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MACHINE STRESS RATING: PRACTICAL CONCERNS FOR LUMBER PRODUCERS.(U)

1977 W L GALLIGAN, D V SNODGRASS, G W CROW

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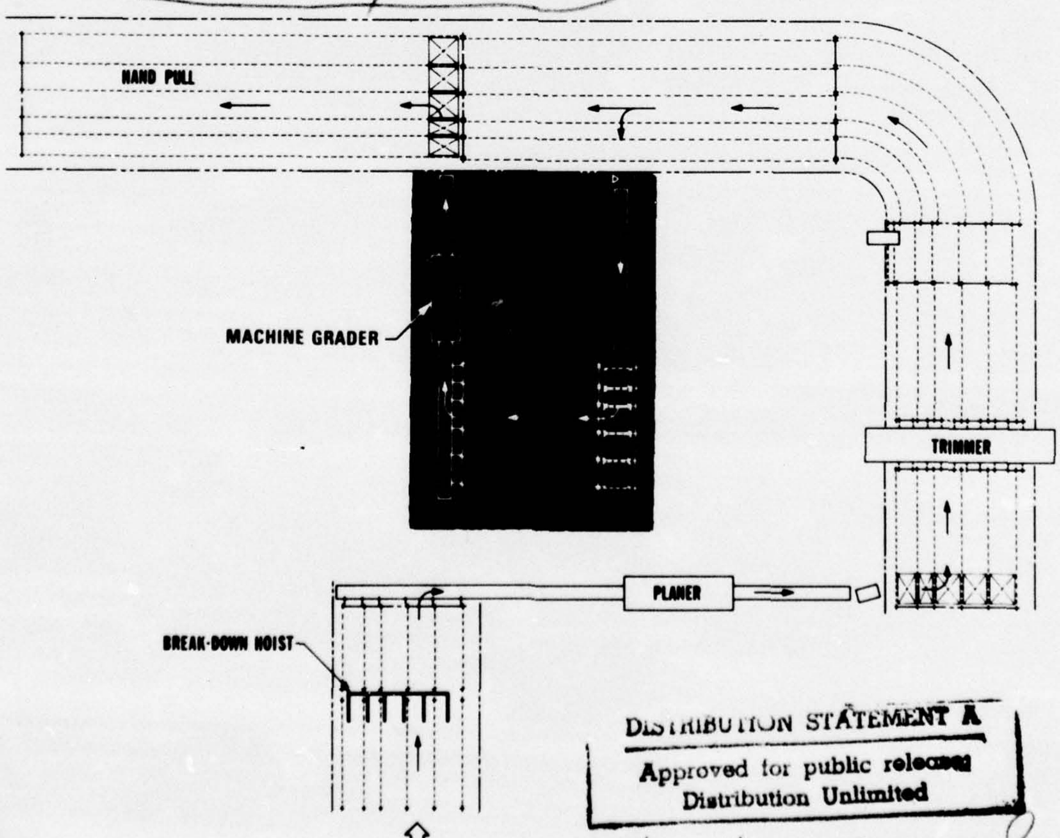

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SUMMARY

Machine grading of lumber has shown great promise in research studies for improving the efficient use of wood. But industry has been slow to put such research findings to use without clear evidence that the change from visual to machine grading will be a profitable one. Mill managers, for instance, need guidelines to consider machine grading and how it might fit into their operations. This report seeks to document those guidelines so that lumber mills may determine for themselves the feasibility of machine stress rating their product.

The first portion of the report deals with the principles of stress grading by machine. In the second part, the methods of lumber yield assessment are described by an industry specialist who has been active in this area. The third portion, on mill mechanical analysis and cost analysis, surveys mills that presently use some form of machine grading--indicating flow diagrams and permitting installation cost estimates.

PREFACE

Machine grading is a reality, but it is surrounded by a maze of truths, half-truths, and plain misunderstandings. The economic significance of all this must be settled in the market place, but many questions have underlying technical answers--and such answers are widely spread among specialists.

The Forest Products Laboratory naturally tries to keep abreast of these and other developments that affect the utilization of wood. This particular publication resulted from specific requests for such information. The Northeastern Lumber Manufacturers Association (NELMA) and the Forest Service's State and Private Forestry unit at Portsmouth, N.H. asked if the Laboratory could summarize information on the principles of machine grading and furnish some idea of costs. Some of this was prepared for them and published in the NELMA Proceedings. But this led to further requests and the present document was prepared.

Naturally, an overview of this magnitude is difficult to prepare, and must be used with care in a particular situation. For instance, the cost estimates would probably not be completely accurate at any single mill. First of all, they are general estimates, and they get outdated quickly. But these numbers do give some general guidance, and furnish a basis for a mill to begin to examine its own situation critically. The procedures and data outlined herein provide an analytical tool for utilization extension specialists to aid in mill yield analysis.

Decisions on whether to go into machine grading and how to approach it must be made by a specific mill on the basis of its own conditions. As usual, producers' associations and consulting engineers will continue to provide the most important role in helping the mill management reach its conclusions.

Produced in cooperation with
State and Private Forestry,
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CONTENTS

MACHINE STRESS RATING: PRACTICAL CONCERNS FOR LUMBER PRODUCERS

By

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Stress grading for structural lumber is nothing new. This has been done visually for six decades, but only in recent years has the concept of stress grading by machine come out of the research laboratory. Recent efforts have indicated a great deal of promise, but it has yet to gain wide acceptance.

The manager of a medium-size sawmill, for instance, may be very interested in any profit potential available to him through mechanical stress grading, but he may lack all the information necessary to evaluate its effect on his operation. His competitors may be talking of machine grading; and because he must remain competitive and has pride in his own mill, he continues to search for ways to update that mill. Yet he has to produce a profit and he must maintain or improve the quality of his product. Can it be done in his situation?

He knows there are problems, not the least of which is his own lack of knowledge about how it could be done, what the potential might be, and what would it cost.

In particular, the producer may wish to apply a combination of grading technologies to make his specific products from the forest resources available. As such, he may want to consider machine grading to supplement his present visual grading system.

This publication seeks to answer some of those questions--and if possible to shorten the delay between the research laboratory and getting the results into practice. To this end, the Introduction to Stress Grading lays the technical background; the second part is Assessing the Production Potential for MSR; and the third is Mill Application of MSR.

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* Consultant to Forest Products Laboratory

I. INTRODUCTION TO STRESS-GRADING[1]

History of Visual Stress Grading

Stress grades for structural lumber came into being approximately 60 years ago because designers wanted safe and economical working stresses. A set of basic grading rules with its assigned stress values was published by the U.S. Forest Products Laboratory in 1923. These stress grades, designed for only the better lumber cut from the tree, were used essentially unchanged for more than 20 years.

World War II brought dramatic changes in the visual-grading system, with the initial influence being a temporary increase in design stresses. The Army actually employed an 85 percent increase in design stresses. After the war some of the temporary stress increases were made permanent.

A growing demand for timber since World War II has placed pressure on the grading system. As a consequence, other changes were made to more efficiently use the timber resource. The most dramatic recent change was an American Lumber Standard, "Product Standard 20-70," which came into effect in September 1970 (4)[2]. This standard incorporated several unique features, including the assignment of green and dry sizes to accommodate shrinkage of green lumber in place. Under this Standard, a National Grading Rule was written that prescribed uniform grading features for the same dimension grades of all species.

The strong point of the visual-grading system is that it permits production of vast quantities of structural materials that are compatible with a major construction need--light-frame housing. A point of concern with the system is the wide variety of grade-species combinations.

The visual grading system has served the Nation well for many years, but in the 1950's technological and economic pressures introduced a second and somewhat competing system--machine stress rating (MSR). While the balance of this document deals primarily with machine grading, it must be recognized that MSR must be measured and considered against a background of visual grading practice and tradition.

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[1]Presented in part by W. L. Galligan of FPL at the 1975 Forest Products Research Society annual meeting, in Portland, Oreg.

[2]Underlined numbers in parentheses refer to Literature Cited near the end of the report.

History of Machine Stress-Rating

Machine stress-rating is based on principles known for over 20 years. The major significant efforts, however, which brought about a feasible industrial method were due to Potlatch Forests, Inc. in Lewiston, Idaho; the Western Pine Association in Portland, Oreg.; the Commonwealth Scientific and Industrial Research Organization in Melbourne, Australia; and more recently the Timber Research Unit of the Council for Scientific and Industrial Research in South Africa. Each of these organizations produced a commercial grading machine using essentially the same principles of the relationship between the stiffness of the piece and its bending strength. These principles permit a grading system less oriented to species--one that produces fewer grades than present visual grading.

Commercial machine-grading was begun in the United States in approximately 1963. While the machines were enthusiastically received, their operation was hampered by misunderstandings of the marketing of mechanically stress-rated lumber and a lack of uniform quality-control procedures. For example, some producers found they did not have sufficiently good moisture control or dimension control; poor mill operation and MSR could not exist together. Similarly, the technical understanding of MSR operation was not uniform; tests made on mechanically stress-rated lumber in the early years suggested that changes were necessary.

Quality-control procedures then were formalized and made the responsibility of the grading agencies in the same manner as visual grading is regulated. In addition, visual restrictions on edge-knot size were placed upon the lumber.

Mechanical stress-grading was initiated more because of producer interest than because of consumer interest. As a result, some early grades were not entirely relevant to marketing needs. This resulted in gradual changes in grade descriptions as this technology evolved. The advent of the MSR system inspired research in many parts of the world, and now more is understood about the fundamentals and their extension to grading criteria and to practical commercial equipment.

Early users of grading machines assumed the market would beat a path to their door. This was quickly shown to be wrong. Market experience suggested that, for lumber producers to determine their capability for machine grading, they should understand (a) some of the basic philosophy of mechanical stress-grading, (b) more about marketing lumber for specific markets, and (c) the potential grading economics

of their own raw material. Companies now active in machine grading in the United States generally have developed a sophisticated appreciation for their potential as producers of structural lumber.

The mechanical stress-grading system is not yet widely used in the United States. One major U.S. inhibition to the system stems from its commercial competition with the visual-grading system. The two systems, functioning differently, may "disagree" in sorting the same lumber, thus implying that some graded material may not be suitable for the intended end use. Therefore, the producer interested in understanding the options of existing grading processes must compare the visual grading yield of his lumber with the potential yield of coexisting MSR and visual grading.

Theory and Practice of Machine Stress Grading

All grading systems are based on the use of predictors to estimate strength properties. In visual grading, for example, the size of visual defects such as knots is used to predict strength. In machine grading in the United States, the combination of edge-knot size and the stiffness of the lumber is used as a predictor.

The relationship between the predictor and the mechanical property of interest is shown by a statistical technique known as a regression. Figure 1 illustrates the use of a regression and the effect of the variability in data on the accuracy of prediction. Clearly the tighter the data group around the regression line, the lower the variability and the better the prediction of strength. Figure 2 is a plot of data from tests of lumber. The modulus of elasticity (E) of the lumber was used as a single predictor of tensile strength. In this figure the regression line is not shown; instead a lower tolerance limit is used. Only a small proportion of the pieces fall below this line. Design values are set from this point based on safety factors and other adjustments.

What predictor to use is a continuing problem; research continues to seek more efficient predictors. To date, the most accurate predictor for bending and tensile strength is E, particularly if measured over short distances.

Some of the characteristics of MSR are better understood if contrasted with the characteristics of the more familiar visual-grading system. One of these characteristics is the variety of design values available with the two grading systems.

For visual grading, the National Grading Rule provides for many design property levels for the same visual grade, as a function of species. For example, figure 3 shows how the bending stress design values compare for some typical structural light-framing grades. Grades compared are Nos. 1, 2, 2 dense, 2 medium grain, and 3. Design bending

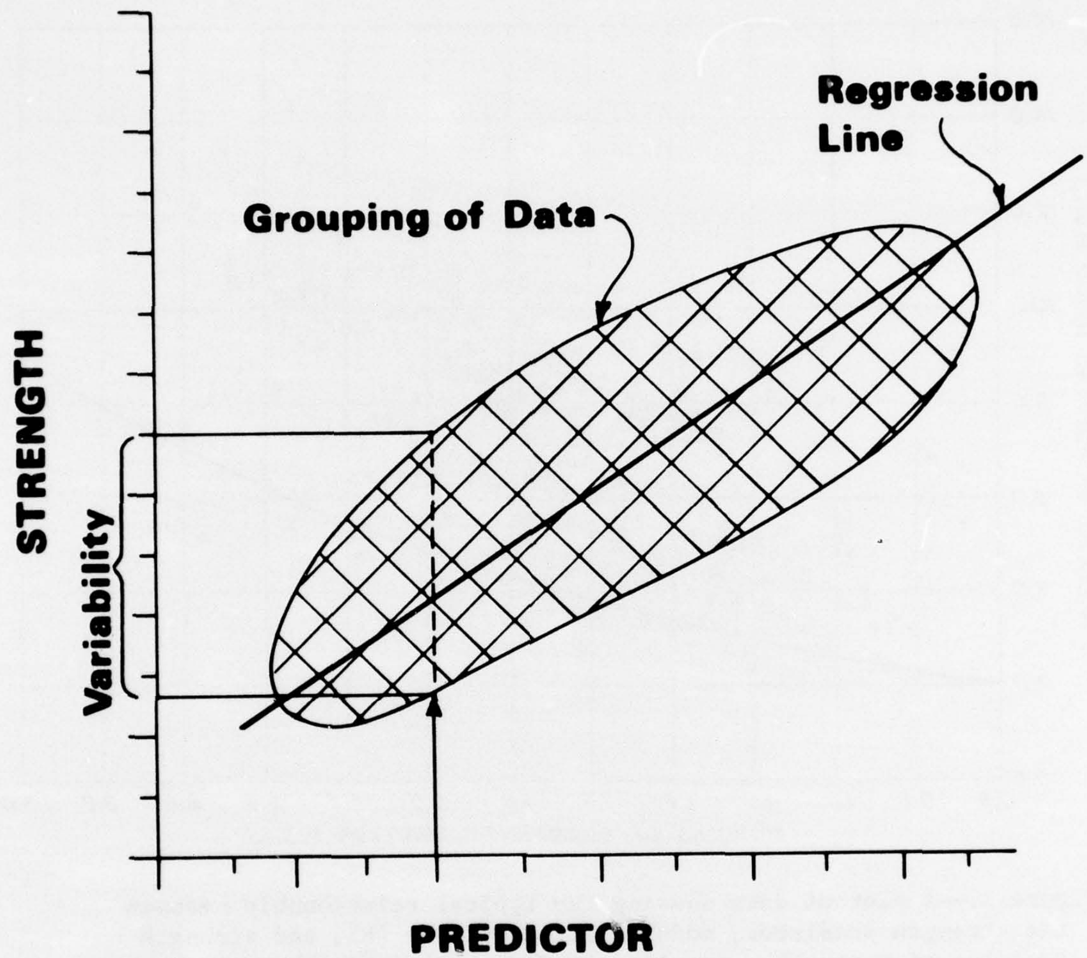

Figure 1.--Predicting strength by using a predictor measured on each piece.

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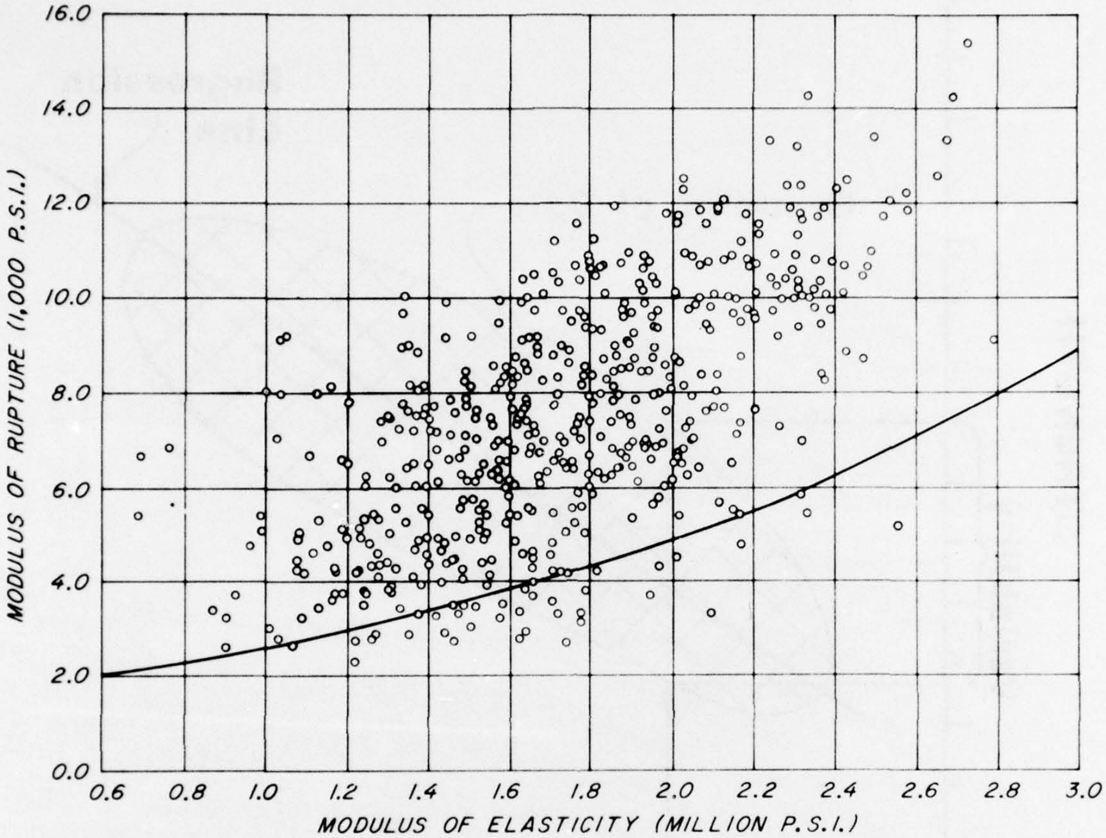

Figure 2.--A plot of data showing the typical relationship between the strength predictor, modulus of elasticity (E), and strength (modulus of rupture). The line is drawn to assure that about 95 percent of all data will be above the line.

(M 139 122)

Allowable design bending strength F_b	So. Pine (19 % MC)	So. Pine (15 % MC)	Douglas-Fir, Larch	Hem-Fir	Eastern Spruce	Spruce-Pine-Fir
1900		1 2D				
1800	1		1			
1700	2D		2D			
1600		2M				
1500	2M		2			
1400		2		1		
1300	2				1	
1200				2		1
1100					2	
1000						2
950						
900		3				
850	3					
800			3			
750						
700						
650				3		
600					3	
550						3
500						

Figure 3.—A comparison of bending strength values of different American Lumber Standard approved Structural Light Framing grades (Nos. 1, 2, 2 medium grain (2M), 2 dense (2D), 3).

(M 144 546)

stress values, F_b, assigned in accordance with the visual stress-grading process are shown in the left-hand column. Although for any one grade (No. 1, for example) the visual grade descriptions (same knot size, same slope-of-grain requirements, etc.) are the same, different design values result, depending on species. This procedure is an effort to achieve maximum marketing efficiency within many species; however, the segregation results in a wide number of grades in the marketplace. For example, over 80 different design values are available for grades of 2 by 4's.

By contrast with the visual-grading system, there are few MSR design values--approximately 10--for 2 by 4's set up under the National Grading Rule; this results because MSR grades have single design values instead of varying by species as with visual grades (fig. 3).

Because MSR uses a machine to sort lumber into grades by E, the result is MSR grades of less variability in E than comparable visual grades (1). To illustrate the comparison, figure 4 shows the dispersion of E in Standard Grade western hemlock. Figure 5 illustrates that visual grading in two different mills can result in different stiffness distributions with the same species (1). By contrast, the MSR grades tend to be more restricted in E distribution by the grading machine function. Figure 6 illustrates E distribution data reported for one mill (1). The variability in E and the difference in E distribution between mills is an essential element in exploring the grading options of a mill. This complex problem requires a deliberate assessment technique, as will be discussed in detail later.

Implementation of Machine Stress Rating

Most lumber that is machine stress-graded in the United States is graded under the auspices of the American Lumber Standard (ALS). Thus, it has the same legal and procedural backing as do the ALS visual grades. These machine grades are assigned properties as are the visual grades. As with all ALS grades, an official grade stamp is required; in this case it must state that the lumber was machine-graded to distinguish it from visually graded lumber. Under the ALS system and the National Grading Rule, quality control and certification procedures are required. Assuming adherence to these procedures, new or modified grades may be developed to meet market needs as long as certain limitations on edge knot size for different E levels are met as specified in the National Grading Rule.

The implementation of the MSR grading process involves all members of the marketing chain, from the lumbermill to the final distributor. The responsibilities that are particularly important for MSR have been summarized and are discussed in the following sections.

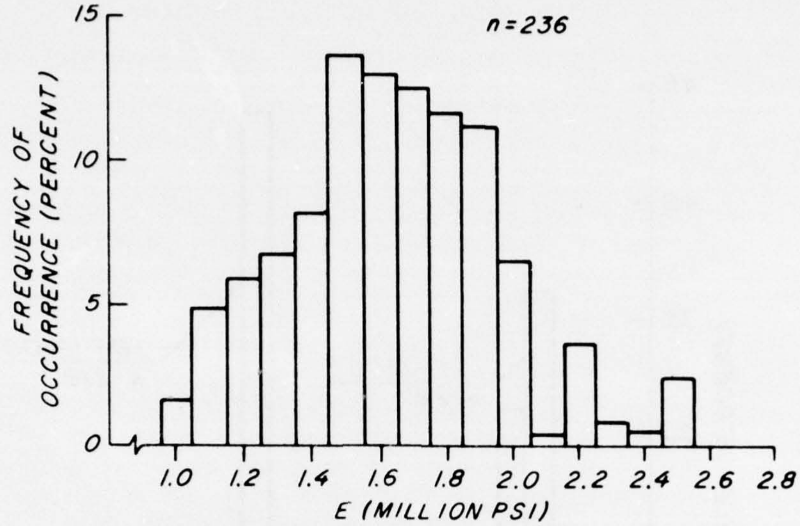

Figure 4.—A histogram showing the variability of E in a sample of Standard Grade western hemlock.

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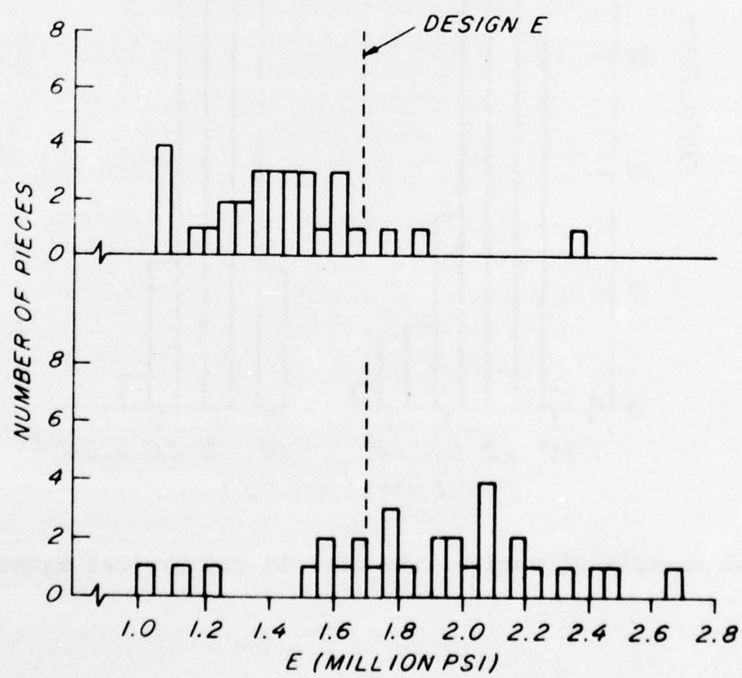

Figure 5.—An example of the difference in E in samples of the same grade of lumber taken at two lumber mills several hundred miles apart.

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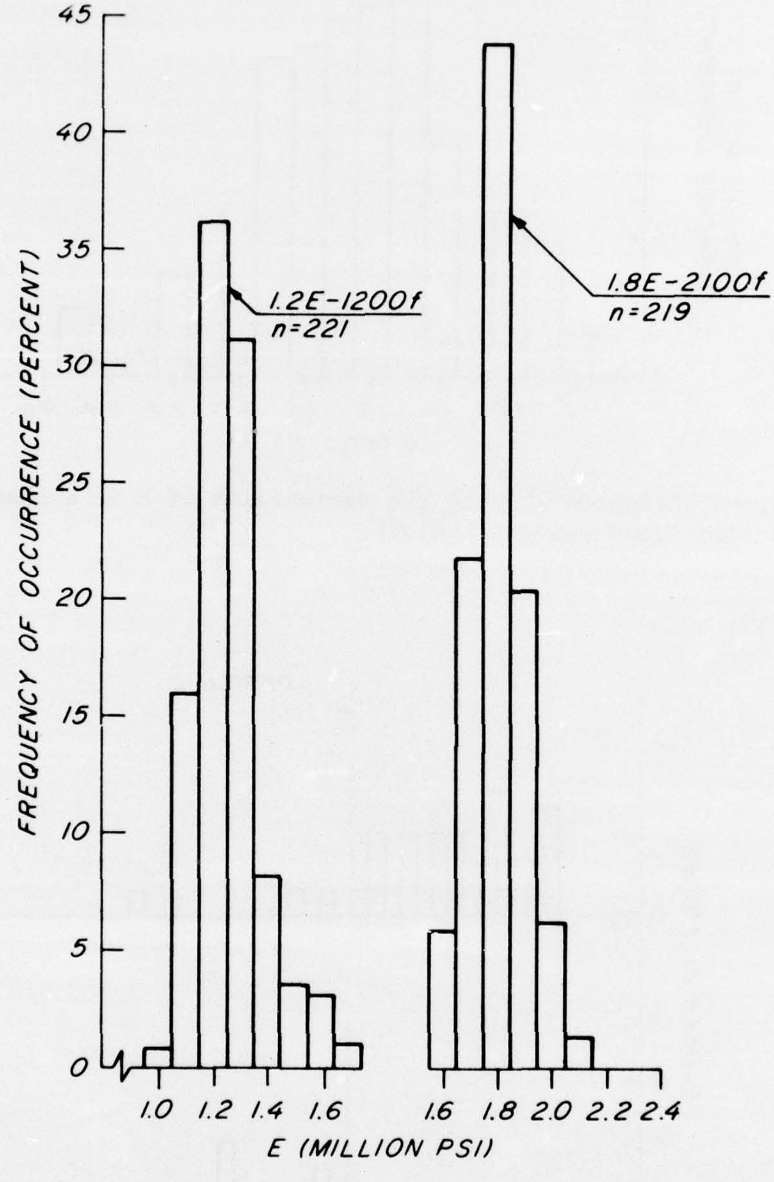

Figure 6.--An example of variability of E in two typical machine grades.

(M 144 561)

Certification and Quality Control

Prior to MSR operation, the supervisory grading agency requires certain certification requirements. This certification procedure is based on sampling lumber and then destructive testing to establish both strength and stiffness. Results permit the grading agency to specify the proper machine operation.

The operation and maintenance of the machine and traditional visual grading supervision takes place on company premises. Daily quality control is required in which lumber is tested for stiffness by grading with agency-prescribed procedures--to assure that the machine is operating properly. The company receives technical support and supervision in its daily quality control program from the agency.

Product Acceptance

The machine stress grades produced must be acceptable to engineers, code authorities, and regulatory agencies. To achieve that acceptance, most companies rely largely on their ability to meet the American Lumber Standard requirements for production and quality control and on that representation by the grading agency or lumber association.

As with visually graded lumber, the grading agency provides the technical and practical data that suggest the capabilities of the grades for marketing use. These data show up in design references such as the National Design Specification (3) as well as in the grading rules. In addition, the grading agency fields questions on specific design applications; they work with authorities in the code and regulatory areas to secure acceptance of property data; they may seek variances in existing practice to make the grading process compatible with the needs of their mills; and they often anticipate technical or interpretive questions from engineers and scientists in design or application positions.

Present Machine Stress-Rating Operations

Domestic Operations

The number of MSR grading operations in the United States has remained rather constant from the mid-1960's to about 1973. Although influenced by general economic conditions, the trend now appears to be a slow increase, accompanied by shifts to modernization and increased production capacity in new installations. More detail on specific MSR installations will be covered later in this report.

The primary market for mills presently in production is structural light-framing grades for trusses. The highest strength grades are

being used for speciality trusses such as those manufactured by the Trus-Joist Corporation. "Medium" level structural light-framing grades, such as 1500f and 1650f, generally are sold for trusses manufactured by metal plate truss procedures. Limited markets are also opening up in such areas as scaffold plank and laminating stock.

Foreign Operations

Machine stress rating originated in Australia because of the need to have more accurate stresses for lumber used in trusses made from Monterey pine grown in New Zealand. The Australian Laboratory developed a commercial machine, the Computermatic, which is now operating regularly in Australia, New Zealand, and England. Numerous installations are active or planned in northern Europe, including Scandinavia. In many instances, the producing firms are concentrating new emphasis on stress grading in the northern European structural framing market.

The South African government laboratory has developed a small machine called the TRU which is being used to grade lumber for trusses, both in producing mills and in truss plants. Approximatelv 40 of these units are in use.

In general, more machine stress-rating installations exist in other countries than in the United States; these are supported by coincident research and development germane to local needs. Market conditions and traditions of stress grading, of course, vary between each of these geographic areas.

II. ASSESSING PRODUCTION POTENTIAL FOR MSR[3]

A company that is contemplating machine grading must evaluate the impact of such a process, both in the mill and in the marketplace. This evaluation requires knowledge, not only of how much MSR lumber of various grades the available lumber resource will produce, but also the grade content and quantities of the residual lumber that will not be machine graded. The economic evaluation depends on the total product mix being produced at a mill, its market value, and the cost of production.

MSR can affect the economic return either favorably or unfavorably, depending upon the specific production and marketing circumstances. The difficulty of assessing the production potential of MSR has been

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[3]Presented in part by D. V. Snodgrass of Simpson Timber Co., at the 1975 Forest Products Research Society annual meeting in Portland, Oreg.

a long-standing problem. In 1970 R. J. Hoyle, Jr. gave a paper in which he presented some MSR yield estimates made in the early 1960's (2). Hoyle's report was a unique analysis of the potential of MSR because it dealt frankly with production and grading realities. Readers will find the yield comparisons between species and geographic regions of particular interest. Much of what is reported was based on data obtained early in the period of MSR development; because the concept of visual restrictions as presently used was not included in the yield analyses, MSR in the Hoyle paper is not synonomous with the term as applied in 1976.

The present discussion of the production potential for MSR updates the Hoyle process to reflect current visual restrictions, market potential, and quality control concepts. It includes information on available equipment and coincident industrial practices.

This report is limited to estimating the change in product mix if MSR were introduced into a mill currently producing dimension lumber and graded by the traditional visual process.

An example from actual experience demonstrates the method of estimation. This example is limited to 2 x 4 Hem-Fir and to estimating the production capability of this 2 x 4 lumber resource with respect to three of the higher MSR grades. The basic method or procedure of estimating is applicable to lumber resources of different sizes and species, as well as other MSR grades. Of course, the results of such an estimate may be significantly different from the example. The estimating method consists of the practical interpretation of appropriate statistics, sampling, lumber production, grading rules, lumber marketing, grading machine behavior, and mechanical properties of lumber. No in-depth treatment of any of these fields of endeavor is intended, as this example only illustrates a basic analysis technique.

What the Terms Mean

Unfamiliar words often obscure rather than explain. Consider for example, the terms "grading lumber" as opposed to "sorting lumber by grade." "Grading lumber", terminology almost universally used in the lumber industry, seems to imply that the lumber mill has some prerogatives in assigning structural or use values to lumber. These prerogatives in fact rest with those organized bodies responsible for the development of grading rules. The lumber mill enters the lumber grading process after the rules have been established; the mill retains only the responsibility for sorting lumber in accord with these rules. The mill, of course, does have the choice of options within the rules and it is these options that will be discussed here.

The words "machine grading" or "Machine Stress Rating" are doubly confusing because they imply that the grading or sorting by grade will be done by a machine; in fact, MSR uses both men and machines. Machine grading sorts lumber into grades by applying certain visual rules similar to some of those used for visual stress grading, while simultaneously sorting the lumber, by machine, into categories or grades that contain certain stiffness characteristics. Both aspects of the system--characteristics subject to visual inspection and machine-measured stiffness characteristics--limit the grade level that a piece is qualified for. Thus, the grade into which a piece is sorted will be the lowest grade level as determined by either man or machine.

MSR grades are designated by the recommended design values for the grade in extreme fiber stress in bending, F_b, and modulus of elasticity, E. For example, the grade designation "1650f-1.5E" means an MSR grade with an allowable F_b of 1650 psi (pounds per square inch) and an E of 1,500,000 psi.

Slight differences in MSR grade combinations and procedures exist between grading agencies. For uniformity throughout the report, species, grades, and procedures of the Western Wood Product Association (WWPA) form the basis for all illustrations.

The table from the WWPA Special Product Rules (fig. 7) shows the 14 MSR grades contained in the grading rules, their names, and recommended design values (5).

No one mill can produce all these grades at the same time. Probably five grades would be a practical maximum for a mill as limited by production and lumber resource capabilities. The market constraints may reduce this number even further. The analysis that is used must consider all the alternative choices and limiting constraints.

To simplify the discussion to follow the concept of "Visual Quality Level (VQL)" and the terms "VQL-1," "VQL-2," "VQL-3," and "VQL-4" are introduced to indicate the visual characteristics of any given piece of lumber.

For checks, shake, skips, splits, wane, and warp there is only one level of acceptance for all MSR lumber graded under the American Lumber Standard. This level is that applied to No. 2 or Standard Grade in the ALS Joist and Plank, Structural Light Framing, or Light Framing rules. The size of allowable edge knots is different for each of the four "Visual Quality Levels" contained in the MSR rules

MACHINE STRESS-RATED LUMBER
2" and Less in Thickness
2" and Wider
Recommended Design Values in Pounds Per Square Inch

f E Classification	Extreme Fiber Stress in Bending Fb (1) Single	Extreme Fiber Stress in Bending Fb (1) Repetitive	Modulus of Elasticity E	Tension Parallel to Grain Ft	Compression Parallel to Grain Fc
*1200f — 1.2E	1200	1400	1 200 000	600	950
1500f — 1.4 E	1500	1750	1 400 000	900	1200
1650f — 1.5 E	1650	1900	1 500 000	1020	1320
1800f — 1.6 E	1800	2050	1 600 000	1175	1450
2100f — 1.8 E	2100	2400	1 800 000	1575	1700
2400f — 2.0 E	2400	2750	2 000 000	1925	1925
2700f — 2.2 E	2700	3100	2 200 000	2150	2150
3000f — 2.4 E	3000	3450	2 400 000	2400	2400
3300f — 2.6 E	3300	3800	2 600 000	2650	2650

The above listed f-E classifications are those that have customarily been used for trussed rafters and other engineered 2x4 construction. The classifications listed below are designed to provide MOE levels with corresponding lower Fb requirements, especially for joist use. Although the tables are separated primarily on the basis of rafter and joist use, any f-E classification may be ordered which meets the requirement of design.

900f — 1.0 E	900	1050	1 000 000	350	725
900f — 1.2 E	900	1050	1 200 000	350	725
1200f — 1.5 E	1200	1400	1 500 000	600	950
1350f — 1.8 E	1350	1550	1 800 000	750	1075
1800f — 2.1 E	1800	2050	2 100 000	1175	1450

Douglas Fir & Larch	Hem-Fir	Pine (2)	Engelmann Spruce—Alpine Fir	Cedar (3)	Western Hemlock
Compression Perpendicular to Grain "Fc ⊥" (DRY)					
385	245	190	195	265	280
Horizontal Shear "Fv" (DRY)					
95	75	70	70	75	90

(1) The tabulated Extreme Fiber in Bending values "Fb" are applicable to lumber loaded on edge. When loaded flatwise, these values may be increased by multiplying by the following factors:

Nominal Width (In.)	3"	4"	6"	8"	10"	12"	14"
Factor	1.06	1.10	1.15	1.19	1.22	1.25	1.28

(2) Idaho White, Lodgepole, Ponderosa or Sugar Pine

(3) Incense or Western Red Cedar

Figure 7.--Ratings listed in Western Wood Products Association, Special Product Rules, 1976 edition.

and is specified as a fraction of the cross section. These VQL's correspond, in turn, to levels of F_b for which a piece of lumber is qualified under these rules (assuming E levels are also satisfied). This relationship is illustrated in table 1.

Further comparison of the VQL requirements for MSR lumber to the characteristics of visually graded lumber will be useful to identify visual lumber grades that will supply the material for the MSR grades of interest.

The visual appraisal of knots for MSR lumber is limited to edge knots only, with the rule also providing that knotholes, burls, distorted grain, or decay partially or wholly at edges of wide faces must not occupy more of the net cross section than the equivalent edge knot.

The criteria for visual grades, on the other hand, are based on sizes of both "edge" and "elsewhere" knots as well as other visual characteristics such as checks, shake, skips, wane, warp, pitch and pitch streaks and pockets, slope of grain, stain, and unsound wood.

The edge knot restrictions for MSR are very nearly equal to those applied to certain visual stress grades as shown in table 2.

The maximum allowable edge knot size for various lumber sizes and grades in both visual stress grades and MSR are detailed in table 3. This table demonstrates that, for example, while the edge knot requirements for Select Structural are similar to those for MSR VQL-1, a slightly larger edge knot is permitted. Thus, Select Structural 2- x 3-inch lumber (1/2 in. maximum edge knot) will be sorted into both VQL-1 (7/16 in. maximum edge knot) and VQL-2 (5/8 in. maximum edge knot) classes by the visual grading requirements of the MSR rules. Estimation of the potential of MSR from existing visual stress grades must take these differences into account to provide appropriate data.

One approach to categorizing quality criteria is either by "structural quality," which affects the strength of a piece of lumber primarily through the relative knot size, or by "appearance quality," which limits the usefulness or market acceptance of a piece by other criteria. Thus, a piece of lumber may have high strength and stiffness, giving a structural quality equivalent to Select Structural, but because of warp or skip, the piece will be properly assigned to No. 3 or Utility grade for marketing. In the MSR grading or sorting system the structural quality criterion is emphasized more than in the visual grades because, as noted, the "appearance quality" limitations are equivalent to visual No. 2 for all structural quality levels (E levels).

Table 1.--Definition of MSR Visual Quality Level, in terms of maximum edge knot size, other visual characteristics, and allowable bending stress[1]

Visual quality level	Maximum edge knot size as fraction of cross section	Other visual characteristics: checks, shake, skips, splits, wane, and warp	Range of accepted F_b, in psi
VQL-1	1/6	Equal to No. 2 or Standard Visual Grades	up to 3300
VQL-2	1/4	"	up to 2050
VQL-3	1/3	"	up to 1450
VQL-4	1/2	"	up to 900

[1] National Grading Rule (under American Softwood Lumber Standard, PS-20-70).

Table 2.--Approximate equivalent edge knots

	MSR	Visual stress grades	
VQL	Edge knot as fraction of net cross section	Structural Light Framing or Joist and Plank Grade	Edge knot as fraction of net cross section[1]
1	1/6	Select Structural	1/6+
2	1/4	No. 1	1/4+
3	1/3	No. 2	1/3+
4	1/2	No. 3	1/2

[1] Sizes computed as a fraction of actual cross section are slightly larger than the fraction shown, signified by "+".

Using this simplified approach of simultaneously exercising judgment with respect to two criteria to sort lumber by grade we can develop an understanding of relationships that exist between visually stress-graded lumber and machine stress-graded lumber. This understanding is useful in identifying the portion of the visually graded lumber that can be machine stress graded.

One way to visualize the effect of sorting by two criteria is to construct a chart that divides a field vertically by one criterion and horizontally by the other criterion. This has been done in figures 8, 9, and 10 for visual stress grades, the MSR-VQL, and the MSR grades.

Figures 8 and 9 show how acceptability for both visual and machine stress grades is limited with respect to edge knots and to characteristics other than knots. These figures can be directly compared because they contain the same lumber. In a sense only the titles have changed. While the lines drawn by the rules are not quite as precise as indicated, some general conclusions can be drawn with respect to the questions "What portions of the visual grades of lumber are qualified for and what portions are not qualified for machine stress grading?"

1. All 2-in. dimension of No. 2, No. 1, or Select Structural grades can be machine graded.

2. All 2-in. dimension of Standard and Construction (Std. and Btr.) grades can be machine graded except for that portion of Standard grade that has edge knots larger than one-half the cross section. (table 3 and fig. 9.)

3. Only that portion of No. 3 grade that is No. 3 solely because of knot size can be machine graded. (figs. 8 and 9.)

4. No Utility[4] or Economy is qualified for machine grading. (table 2 and figs. 8 and 9.)

Conclusions 3 and 4 are not precisely true because of differences in handling of unsound wood or decay in the two different grading systems. However, the frequency of exceptions to these conclusions is so small that, for the practical purpose of the initial assessment of MSR production potential at a mill, the Utility and Economy grades can be assumed to contain no lumber suitable for an MSR grade.

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[4] Utility grade is not demonstrated in charts, but by definition it contains knots larger that those contained in Standard grade or it contains other visual characteristics larger than those in Standard grade. Therefore, utility grade is ineligible for inclusion in the MSR grades.

Table 3.--Comparison of size of maximum allowable edge knots in visual and machine stress rating (MSR) grades[1]

Lumber Size	Machine stress rating VQL-1	Visual Select Structural	Machine stress rating VQL-2	Visual No. 1	Machine stress rating VQL-3	Visual No. 2	Visual Construction	Machine stress rating VQL-4	Visual No. 3	Visual Standard	Visual Utility	Visual Economy
2 x 3	7/16	1/2	5/8	3/4	13/16	7/8	1-1/4	1-1/4	1-1/4	1-1/2	2	Not limited
2 x 4	9/16	3/4	7/8	1	1- 3/16	1-1/4	1-1/2	1-3/4	1-3/4	2	2-1/2	
2 x 6	15/16	1-1/8	1- 3/8	1-1/2	1-13/16	1-7/8		2-3/4	2-3/4			
2 x 8	1- 3/16	1-1/2	1-13/16	2	2- 7/16	2-1/2		3-5/8	3-1/2			
2 x 10	1- 9/16	1-7/8	2- 5/16	2-1/2	3- 1/16	3-1/4		4-5/8	4-1/2			
2 x 12	1- 7/8	2-1/4	2-13/16	3	3- 3/4	3-3/4		5-5/8	5-1/2			

[1] Grading Rules for Western Lumber, 3rd Edition, Western Wood Products Association, Portland, Oreg. Size in inches to the nearest 1/16 in.

VISUAL GRADE SORTING CRITERIA OTHER THAN KNOTS

(Checks, shake, skips, wane, and warp, pitch, pockets, slope of grain, stain, and unsound wood.)

VISUAL GRADE KNOT SORTING CRITERION

Visual Grade Level	Sel Struct	No. 1	No. 2	No. 3	Econ.
Sel Struct	SS	1	2	3	E
No. 1	1	1	2	3	E
No. 2	2	2	2	3	E
No. 3	3	3	3	3	E
Econ.	E	E	E	E	E

Figure 8.--Relation between knot sorting criteria and sorting criteria other than knots for visual grades. Portion of visual grades not eligible for MSR because of visual characteristics is shown by shaded area.

(M 144 542)

		VQL KNOT SORTING CRITERION				
		1/6	1/4	1/3	1/2	Larger than 1/2
		Approximating-				
	Visual Grade Level	Sel Struct	No. 1	No. 2	No. 3	Econ.
VQL SORTING CRITERIA OTHER THAN KNOTS (Based on relative visual grades)	Sel Struct	VQL-1	VQL-2	VQL-3	VQL-4	NA
	No. 1	VQL-1	VQL-2	VQL-3	VQL-4	NA
	No. 2	VQL-1	VQL-2	VQL-3	VQL-4	NA
	NO. 3	NA	NA	NA	NA	NA
	Econ.	NA	NA	NA	NA	NA

Figure 9.—Relationship between VOL knot sorting criteria and VQL sorting criteria other than knots--both relative to visual grade criteria. The National Grading Rule does not permit visual characteristics in the shaded area in MSR grades.

(M 144 541)

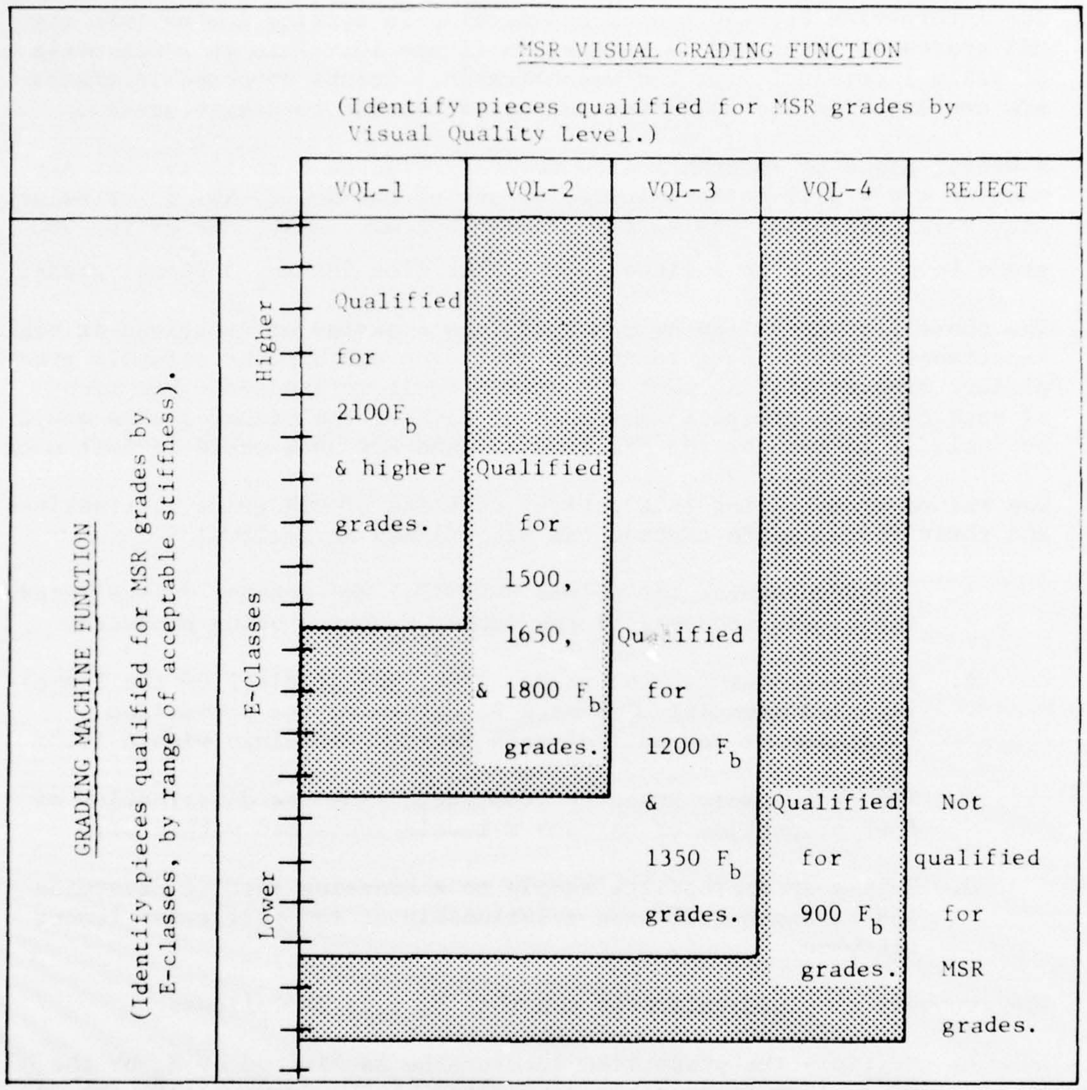

Figure 10.--Illustration of interaction of visual grading function (by grader) and the grading machine function (by machine) in sorting lumber by the MSR grade rules.

(M 144 540)

The interaction between grader and machine in sorting lumber into the MSR grades is portrayed in general in figure 10. This is a schematic of table 1 combined with E-class criteria. Groups of possible grades are contained in the divisions shown, as opposed to single grades.

A useful piece of information conveyed by figures 8 to 10 is that any machine grade will contain lumber of any of the No. 2, No. 1, or Select Structural grades of the visual grading system. Also, MSR of the 900 F_b grade level will also include some lumber from the No. 3 visual grade.

The above statements can be reworked into a series of questions of real importance: "If we were to change over from our current visually graded product line at mill X, what MSR grades could we produce? How much of each could we produce? How much of each of the visual grades would be included in each of the MSR grades? And how much would be left over?"

One method of obtaining this desired estimate of MSR grade alternatives and their visual grade content can be outlined as follows:

A. First determine the volume (MBF/YR.) and content (visual grades, sizes, and species) of the lumber resource being produced.

B. For each item (visual grade, size, and species) of the lumber resource identified in step A, determine the proportion (fraction or percent) of each MSR-VQL contained within it.

C. For each lumber resource item, determine the distribution of E or proportion of various E levels contained within it.

D. Submit an appropriate sample to a breaking test to determine the strength-stiffness relationship of the particular lumber resource.

The recovery or yield estimates can then be made as follows:

1. Multiply the proportion recoverable as limited by E, by the proportion recoverable as limited by VQL (step B), to obtain the proportion recoverable as MSR lumber from the lumber resource item (visual grade, size, and species) currently being produced.

2. Estimate the proportion recoverable as limited by E from the data in steps C and D.

The recovery estimate is, in fact, complete at the end of step 1, but the data are split between the various lumber resource items (visual grade, size, and species) and need to be summarized to show the total effect on the product mix. This can be done by reassembling by size and species to show not only the MSR grade recovery estimates but an estimate of the recovery by visual grade of the residual volume.

This final summary of the product mix can then be compared with the value of the current product mix. This comparison, along with factors including cost of installation, effect on total product line, and availability and cost of capital, can be used to decide whether or not to introduce machine grading in a mill.

Establishing Scope of Study

The first step in appraising the MSR production potential of a mill is to establish the scope of the study to develop only data pertinent to the decision to be made. To determine the production potential for all 14 MSR grades from all possible sizes, grades, and species currently being produced in any given mill would generate more data than can possibly be used.

Mill managers and marketing people must appraise the objectives of their mill to set the limits of the investigation. In a recent actual case study, these limits were stated something like this:

> "The market appears to demand primarily 2 x 4's and 2 x 6's in MSR grades of 1650f-1.5E, 2100f-1.8E, and 2400f-2.0E in random-length assortments of 10 to 20 ft. The mill presently produces about 50 percent 2 x 4's, 20 percent 2 x 6's, and 30 percent other widths. Therefore, let us first investigate the production potential of our 2 x 4's with respect to 1650f-1.5E, 2100f-1.8E, and 2400f-2.0E MSR grades. The results of this 2 x 4 study should suggest the overall feasibility, as well as provide guidance for further study with 2 x 6's and other widths and MSR grades."

The demonstration in the next section accepts these limits and addresses itself to the production potential of three MSR grades from the 2 x 4 grades produced at a mill. The data shown are from an actual study made with this objective in mind.

Planning the Study

Now that it has been decided that the investigation will be limited to 2 x 4's and three MSR grades 1650f-1.5E, 2100f-1.8E, and 2400f-2.0E, we can address the questions of:

1. Which 2 x 4 grades shall we investigate?

2. What quantities of these are produced each year?

Review of the MSR grading rules, table 1 or figure 10, shows that the grades we are interested in fall in VQL-1 and VQL-2. The mill presently sorts 2 x 4's in accordance with a combination of the visual Structural Light-Framing and Light-Framing grades. The actual grade mix being marketed is Select Structural, Standard and Better, Utility, and Economy. The Standard and Better combination, of course, contains Standard and Construction grades of lumber.

Review of the conclusions from comparing the grading systems in table 3 and figures 8 and 9 shows that the MSR grades desired come only from the Select Structural grade and the Standard and Better grade mix.

The next step is to obtain actual data on grade yield. All the data needed can be obtained at the mill, except for breaking strength data, which require the services of a testing laboratory. Obtaining the data at the mill requires: A form on which to record data (example, fig. 11), a moisture meter, a static testing device for measuring E, and a qualified lumber grader.

The static tester is a simple mechanical device that applies a dead load to a piece of lumber placed flat on a 4-ft span. This device is an integral part of the MSR grading and quality control system as practiced in the United States and can be built at modest cost from plans available through grading associations. A schematic of a static tester used by several grading agencies is shown as figure 12.

The qualified lumber grader is a key man in obtaining the necessary data for evaluating MSR recovery potential. His job is to carefully appraise each piece to determine that it is of a given visual grade (and not of a higher or lower grade) and to determine its MSR-VQL. If the grader is not accustomed to grading under the MSR system, it is desirable to allow sufficient time for orientation and possibly consultation with grading association personnel. Accuracy in grading reduces the errors inherent in making recovery estimates from relatively small samples.

In generating the data: (a) Select a number of pieces for inspection; (b) record data for visual grade, moisture content, MSR-VQL, and static E for pieces in the sample; (c) select a special sample from (b) to determine the strength-stiffness relationship of the lumber resources.

The sample must represent the entire range of lumber that is to be machine graded, and this is not simple to achieve. Various textbooks

MSR Recovery Estimate - Data Sheet

Size 2x4 Species Hem-Fir Grade Std & Btr.

Date 7/10/74 Comment E. Jones, Grader

WWPA Static Tester, Day Shift Production

	Visual Grade					M.C.	MSR-VQL					E	
Spec. No.	C	S				%	1	2	3	4	R	Defl.	
81	X					7	X					.143	
82	X							X					
83		X				13		X				.181	
84	X					17			X			.147	
85		X									X		
86	X						X						
87		X				12					X	.176	
88	X					11		X				.163	
89		X								X			
90		X				16			X			.113	
91		X						X					
92	X						X						
93		X				9	X					.133	
94	X					12			X			.182	
95	X									X			
96		X								X			
97	X					10	X					.157	

Figure 11.—A simple form for record keeping.

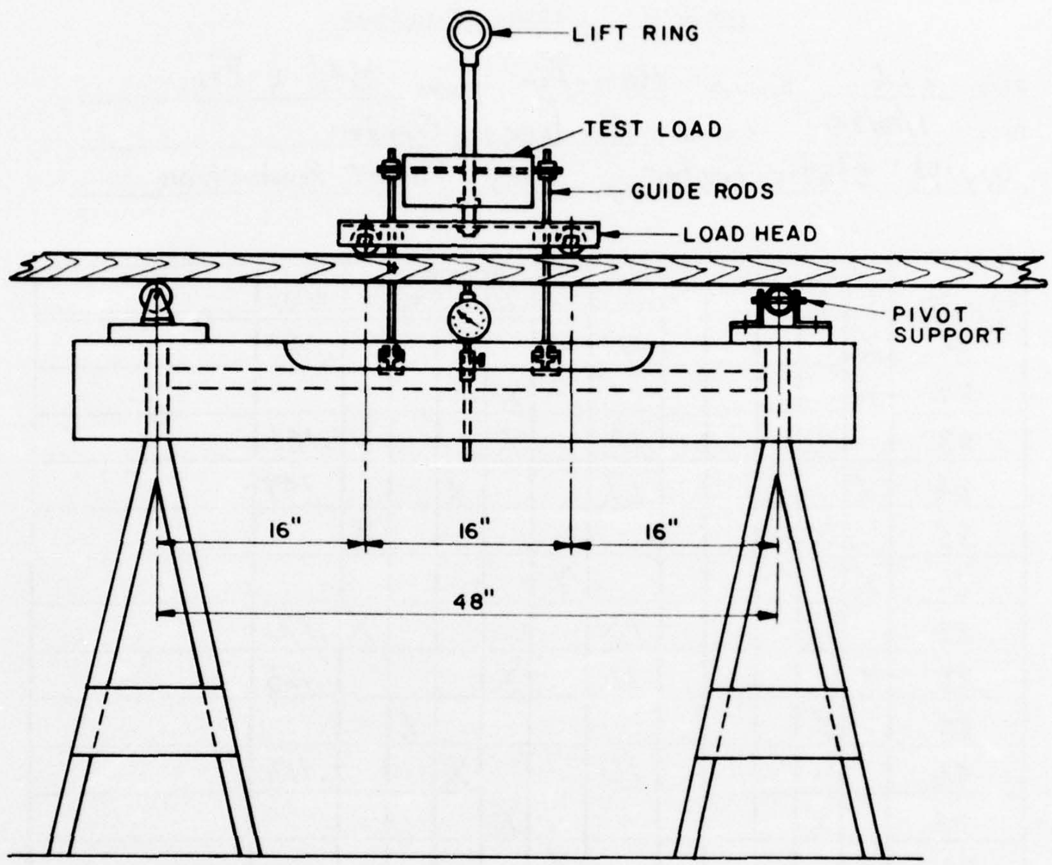

Figure 12.--Schematic of a static bending testing device used for assessment of E and quality control by several grading agencies.

(M 143 918)

on sampling procedures may be followed, but the methods involved in sample collection may become cumbersome when applied to a sawmill operation. Consequently some relaxation of strict rules of sampling may be in order. Experience suggests the following approximate methods can be applied with satisfactory results.

By using samples from current sawmill production we hope to estimate what is likely to happen in the future. But such an estimation rests on the assumption that the timber resource will remain relatively constant. In operating terms, as long as we put logs of the same grade quality from the same geographic area into a sawmill, we can expect to obtain the same lumber product mix. To shortcut the time involved and to assure having a representative sample, select the sample at a time or from a lot of material that experienced mill personnel judge to represent the mill output.

Generate data for each visual grade, size, and species of interest. In our example this is for three grades of 2 x 4: Standard, Construction, and Select Structural.

1. Inspect 200 pieces of each grade to obtain the MSR-VQL data.

2. Inspect 75 to 100 pieces of each grade for moisture content and E. (Alternate pieces of the prior sample).

To help eliminate possible bias in a non-representative lot, obtain these data from two lots of lumber that were produced at two distinctly different times. Inspect a 100-piece sample from each lot. Record MSR-VQL data on all pieces, and moisture content and E data on alternate pieces, to get the desired quantity of data. If, on analysis, the results appear to be about the same for each lot, no additional data should be necessary. If the results appear quite different, obtain data from a third lot of lumber produced at a different time. If one lot remains radically different from the other two, we may suspect an error of some sort or a non-representative lot. We may consider discarding the suspect data and obtaining new information to replace it.

"Procedure for Mill Sample Selection" (Appendix A) provides general guidance for selecting a sample suitable for laboratory breaking tests. Such tests could determine the strength-stiffness relationships of any lumber resource. To make this selection, and subsequently to process the data, we will need to know the VQL and E of each piece sent to the laboratory. Therefore, each piece is marked with its specimen number and sorted by MSR-VQL. Particular pieces are selected, after reviewing the data generated for all pieces.

Gathering the Data

In the example, the production schedule at the mill was such that 2 x 4's would be processed continuously for three to four days with an interval of two to three weeks between 2 x 4 production runs.

To have a representative sample from each of two production runs and to overcome the problem of time to obtain the samples, this sample selection procedure was set up:

> At 10- to 20-minute intervals a man was to pull one piece of each grade of lumber desired--Select Structural, Construction, and Standard. He was instructed to take the first piece of each grade as it came to him. The lumber was grade marked at this point so he had only to read the grade stamp to determine if a piece qualified for the sample. This continued until 100 pieces of each grade were collected from each of the two production runs of 2 x 4's.

Operating personnel selected these initial samples so the collection could be conveniently conducted throughout the three to four days required and during both day and swing shifts. During each production run, 300 pieces were selected for the sample--100 pieces each of Select Structural, Construction, and Standard. The pieces were inspected and tested at the mill as follows:

1. Each piece was visually inspected by a senior grader, to verify the grade shown on the grade mark and determine the MSR-VQL.

2. Alternate pieces were checked for moisture content with a meter and for E by the static test device.

3. Records of all data were kept on a form (similar to fig. 11). The static test for E and record keeping was done by an experienced technician hired specifically for the job. Only deflection is recorded on the data sheet, to eliminate the need for the calculation to an E value while obtaining the data.

To simplify selection of the sampie to be sent to the laboratory, each piece was marked with its specimen number and set aside as sorted by MSR-VQL.

Analyzing the Data

For each of the two production runs an analysis of the MSR-VQL recovery potential from the various visual grades was made (table 4).

Even though Utility grade need not be inspected, it was inspected in the first test run. The results were left in the table to demonstrate that the MSR production potential from Utility grade lumber is small indeed. The fraction recoverable from Utility grade is not included in the final analysis.

Comparing the data of the two test runs, the following observations seem appropriate:

1. MSR-VQL recovery from Select Structural grade was about the same in both runs.

2. MSR-VQL recovery from Standard and Construction grades appear to be different in the two runs.

However, in this instance, the interest was in the recovery of MSR-VQL 1 and 2 only. The data indicate that, for VQL-1 and VQL-2, the recovery potential was 100 percent of the Select Structural, 43.2 to 53.7 percent of the Construction grade, and 18.7 to 27.2 percent of the Standard grade. Because the mill operating people judged that the sample represented the logs they normally worked with, and the variations in MSR-VQL recovery potential could probably be bracketed by assuming ±5 percent when making economic estimates, it was decided to combine the results of the two tests (table 5) and proceed.

At this point, another typical problem was encountered. The mill did not keep records that separated the Construction and Standard grades because this lumber was marketed in the "Std. & Btr." grade mix. To complete the analysis as planned, it was necessary to determine the relative quantities of each grade that was being produced. The method used to do this was to tally the grade marks on samples of 200 consecutive pieces on the chain. This was repeated at approximately 20-minute intervals.

The percentage of each of the visual grades observed was calculated on a cumulative basis for the entire lot and plotted on a graph (fig. 13). Values were 6 percent for Select Structural, 55 percent for Construction, and 22 percent for Standard. From this base the recovery projections for MSR grades would be made.

Table 4.--Recovery potential of two production runs of 2 x 4 MSR-VQL material, showing number of pieces and total percentage

MSR-VQL	Select Structural		Construction		Standard		Utility	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
				FIRST SAMPLE RUN				
VQL-1	110	96.5	31	28.7	14	13.6	0	0
VQL-2	4	3.5	27	25.0	14	13.6	3	2.6
VQL-3	0	0	20	18.5	26	25.2	1	.9
VQL-4	0	0	30	27.8	39	37.9	0	0
Reject	0	0	0	0	10	9.7	111	96.5
Total	114	100.0	108	100.0	103	100.0	115	100.0
M.C.	17.8		16.4		17.0		17.3	
				SECOND SAMPLE RUN				
VQL-1	84	98.8	7	10.4	5	6.7		
VQL-2	1	1.2	22	32.8	9	12.0		
VQL-3	0	0	25	37.4	25	33.4		
VQL-4	0	0	13	19.4	19	25.3		
Reject	0	0	0	0	17	22.7		
Total	85	100.0	67	100.0	75	100.0		
M.C.	14.4		12.7		13.4			

Table 5.--Recovery potential, with first and second test runs combined for 2 x 4 MSR-VQL

MSR-VQL	Select Structural		Construction		Standard	
	Number	Percent	Number	Percent	Number	Percent
VQL-1	194	97.5	38	21.7	19	10.7
VQL-2	5	2.5	49	28.0	23	12.9
VQL-3	0	0	45	25.7	51	28.7
VQL-4	0	0	43	24.6	58	32.5
Reject	0	0	0	0	27	15.2
Total	199	100.0	175	100.0	175	100.0

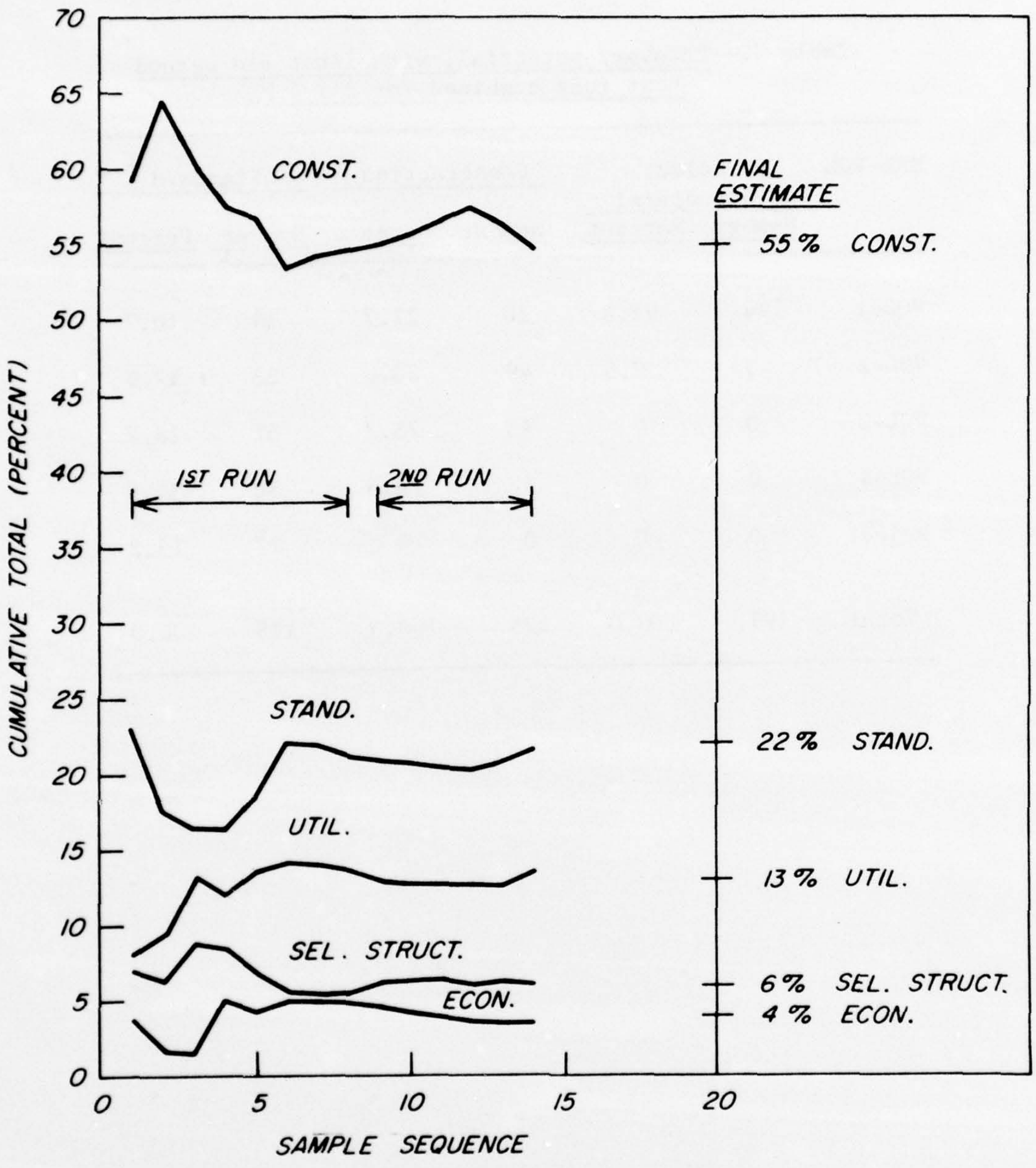

Figure 13.--Estimating percent of each visual grade being produced by taking sequential samples of 200 pieces each, and plotting cumulative percent of grades observed.

(M 143 917)

To determine what quantities of each stiffness category are present in the lumber, a histogram of the percent of each E class of 100,000 psi can be made (figs. 14, 15, and 16). This histogram can easily be constructed by hand; however, if computer facilities are available, programs exist to construct the histogram.

In all instances, the average E observed was higher in the second sample than in the first. The moisture content was observed to be lower in the second sample and was assumed to be the cause of the higher average E. This underscores the need for good drying control to maintain recovery objectives when machine-grading lumber.

The final piece of information needed, the strength-stiffness relationship, was obtained by breaking the selected sample of the lumber in the laboratory and comparing the results.

Appendix A contains the basic procedures for sample selection. Grading agency supervision is desirable; agency procedures may be more specific than the general procedures of Appendix A. Note that the sample sent to the laboratory came from material that had already been inspected. All the data necessary had already been recorded, and it was only necessary to identify the pieces wanted, sort them out, and ship them to the lab.

The next task in the estimating process was to select a minimum average E value to be maintained by the MSR production process. The actual minimum average E required of an MSR grade will result from meeting either of two criteria: (1) The average E must be maintained at a level not lower than specified grade E or; (2) the average E must be maintained higher than specified grade E to satisfy the requirements for the specified bending strength of the grade. The strength-stiffness data developed at the laboratory for our example is shown in figure 17.

From these data, an estimate can be made of the minimum average E required of a grade for bending strength. For this estimate a line is drawn on the graph parallel to the regression line and 1.66 times the standard error below the regression line (fig. 18). This line is an estimate of the 5 percent exclusion level with respect to modulus of rupture (MOR) for the regression data. Again, more sophisticated methods are available but this suggested method has been found adequate for estimating purposes.

Next, find the point at which the 5 percent line is intersected by MOR value equal to 2.1 x the grade F_b. Read from the graph the E value of this point and add 100,000 psi. This estimates the mean E value required for the grade in question. In figure 18, the intersection of 2.1 x 1650 (MOR = 3,465) with the 5 percent exclusion line is at 1.42E; after adding 100,000 psi (0.1E), an estimate of

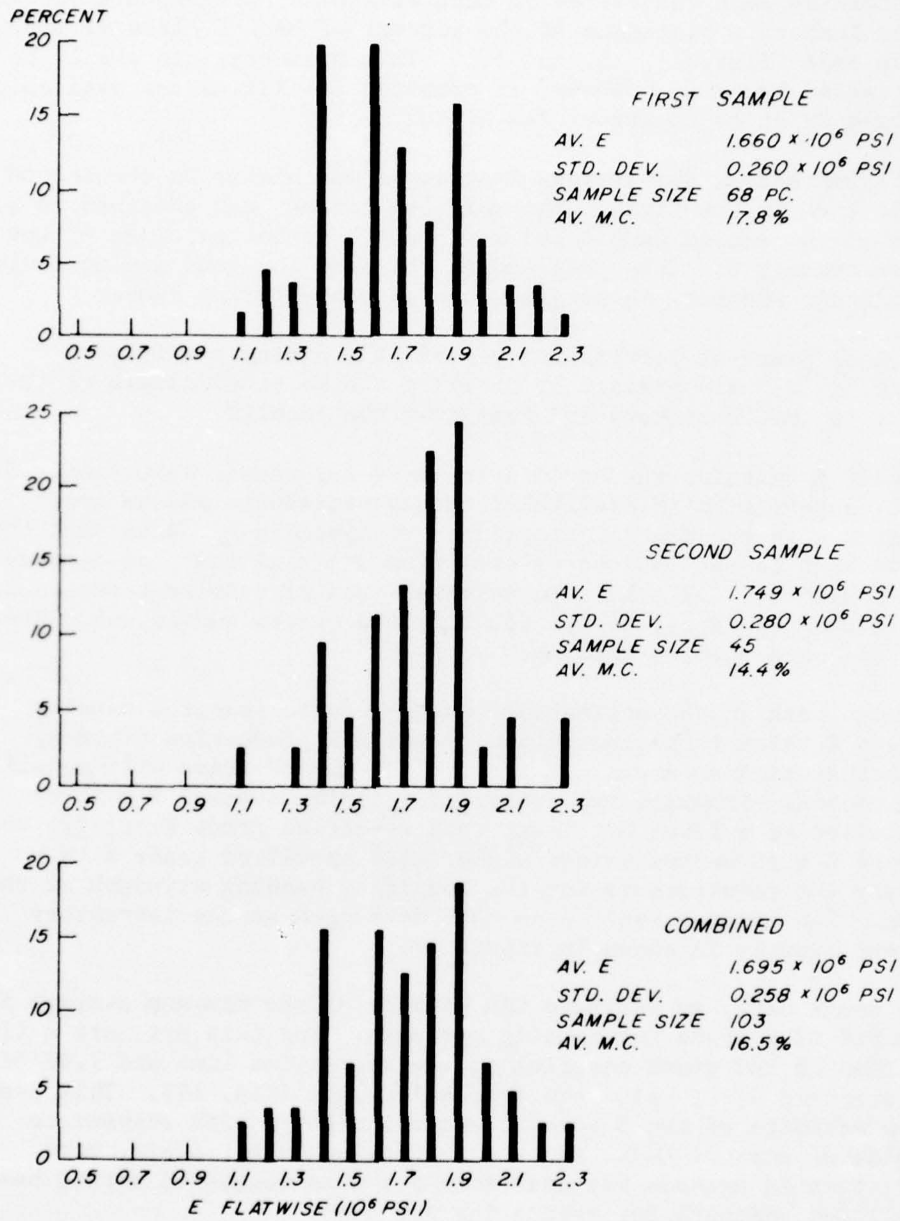

Figure 14.—Select Structural material: Modulus of elasticity flatwise, as measured with static tester on 2 x 4's on two individual samples and their combined results.

(M 143 912)

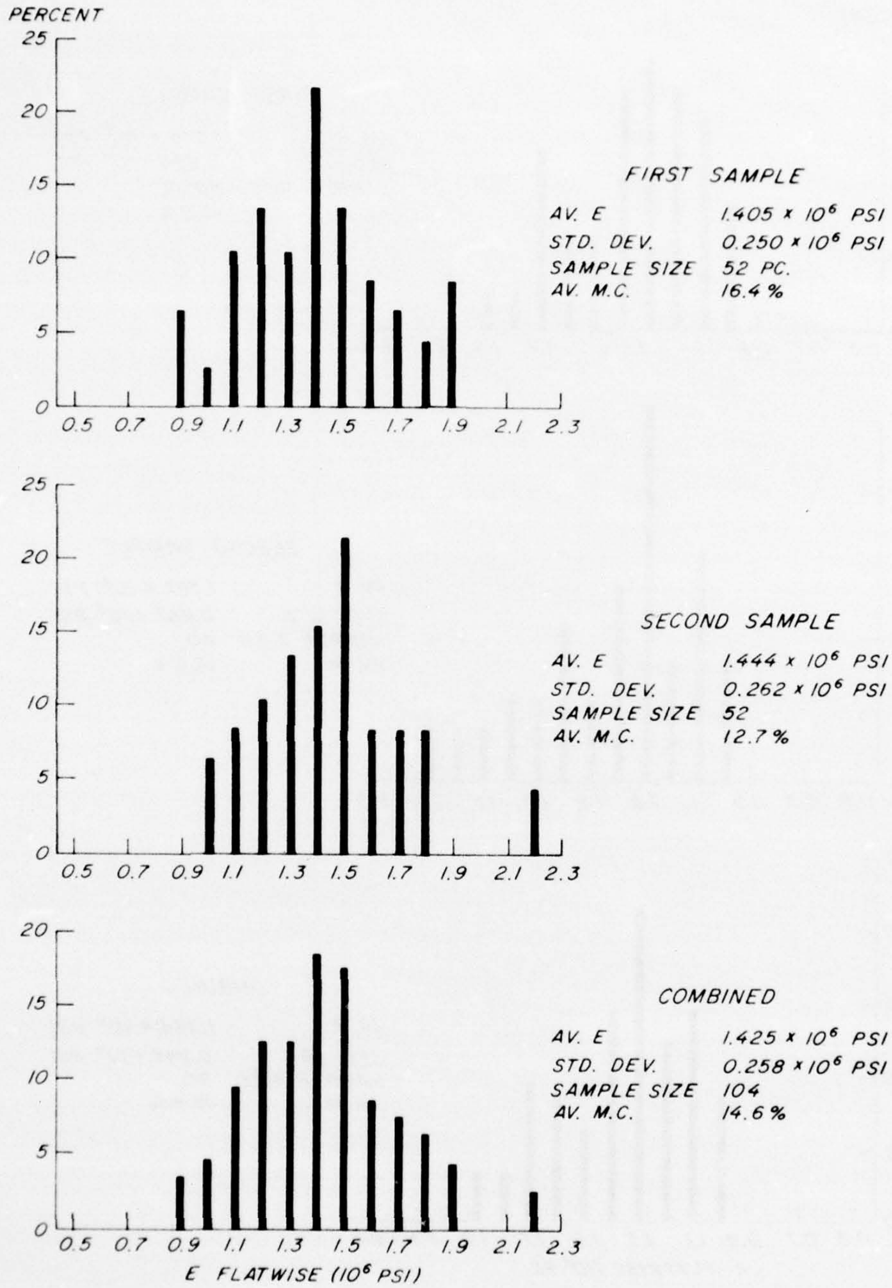

Figure 15.—Construction Grade material: Modulus of elasticity flatwise, as measured with static tester on 2 x 4's on two individual samples and their combined result.

(M 143 913)

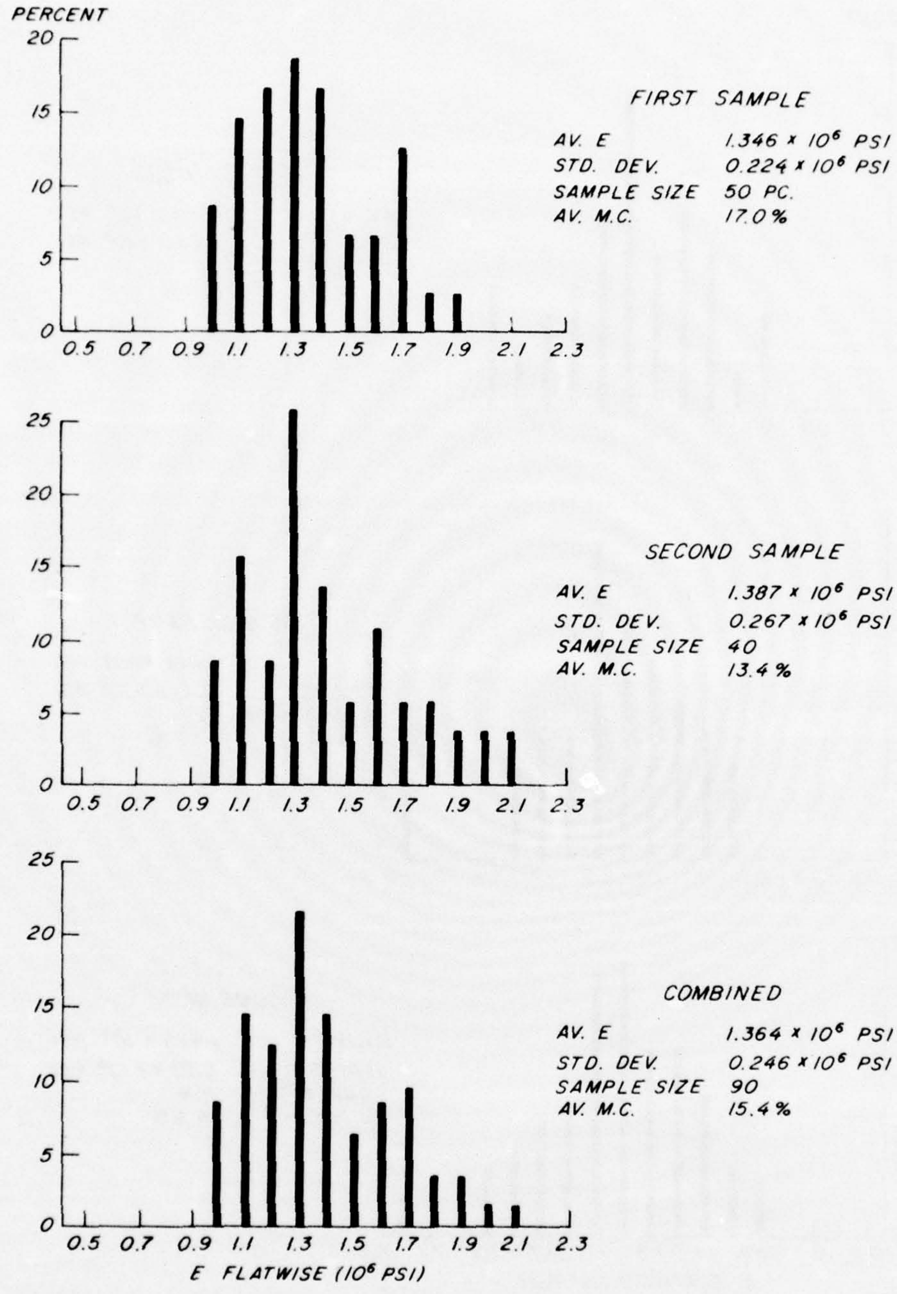

Figure 16.--Standard Grade material: Modulus of elasticity flatwise, as measured with static tester on 2 x 4's on two individual samples and their combined result.

(M 143 915)

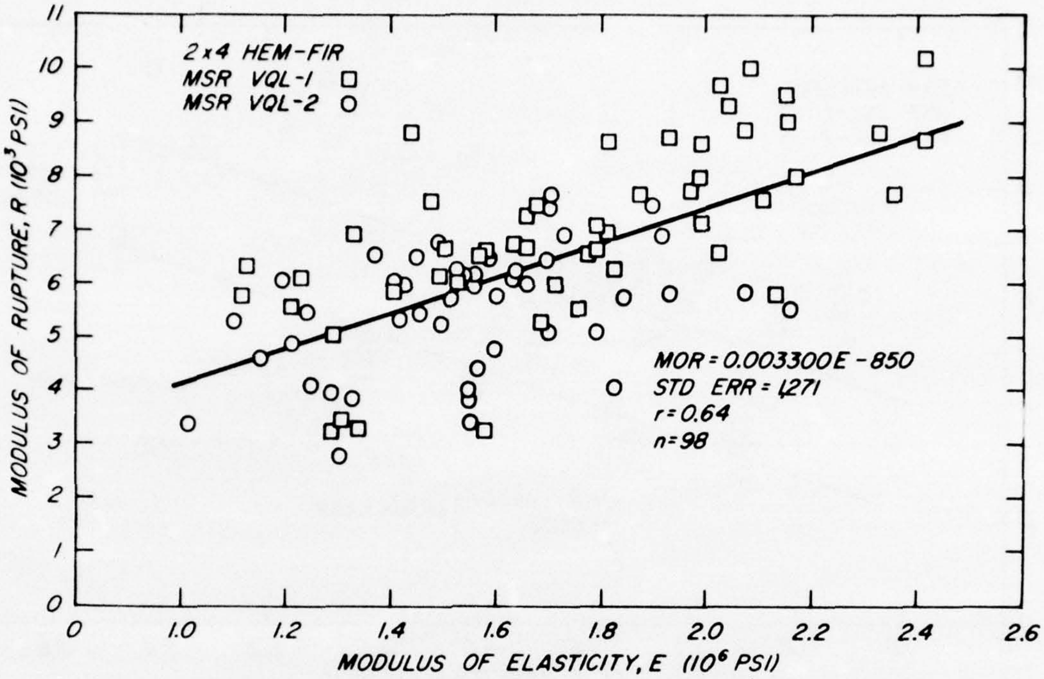

Figure 17.--Modulus of rupture (R) versus modulus of elasticity (E) flatwise, as measured with static tester.

(M 144 335)

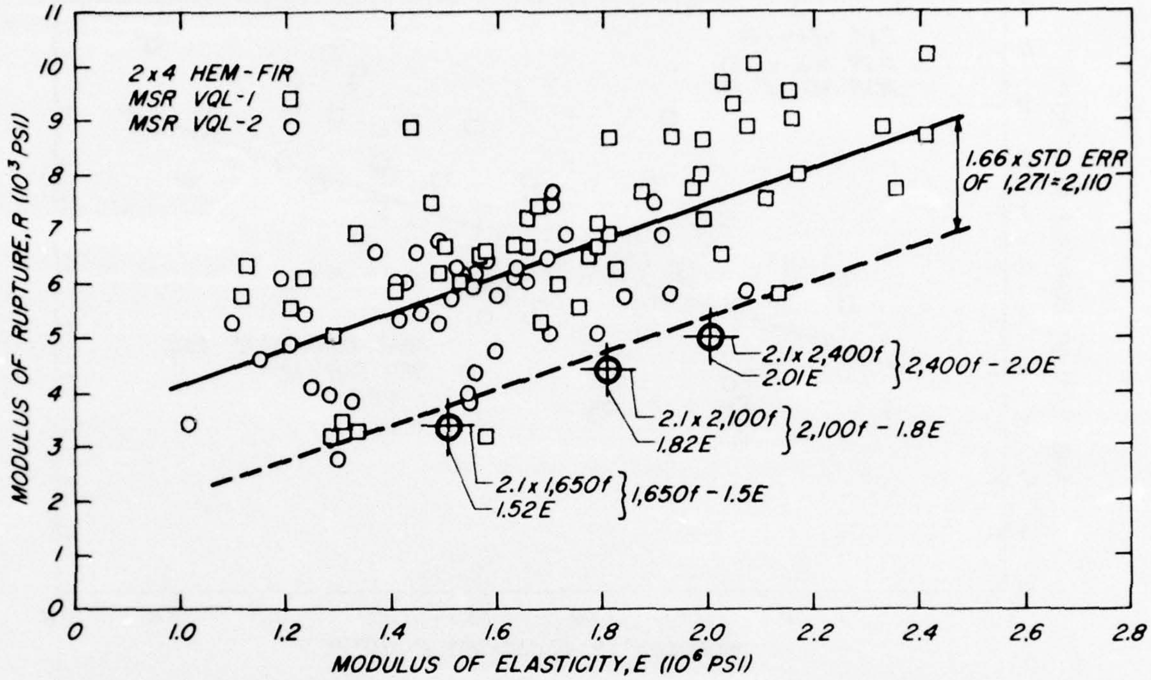

Figure 18.--Estimate of average E required to maintain F_b of grade. The lower line is an estimate of the 5 percent exclusion limit for MOR for purposes of the grade yield estimation process.

(M 144 336)

mean grade E for the 1650 F_b grade will be 1.52. Note that this is slightly higher than the required grade E of 1.50. Both the conditions of grade E and grade F_b must be met simultaneously; therefore use the larger of the two values when estimating recovery. In the example here, the average E required for each grade of interest is, in each case, just slightly higher than grade E:

Grade	Average E from graph
1650f-1.5E	1.52
2100f-1.8E	1.82
2400f-2.0E	2.01

This method of estimating average E required was developed as a rule of thumb from monitoring breaking tests of the grade output of an operating machine grading system over a period of several years. It is both judgmental and empirical in nature and further experience may improve on the method. (Another way to obtain this estimate when using the entire W.W.P.A. procedure (5) is to select, as the minimum average E for a grade, the value associated with an "A" of 3 percent as provided in the W.W.P.A. certification method procedure. Experience has shown that this number and the one selected from the graphic method just illustrated are nearly the same.)

Having estimated the average E required for each MSR grade of interest, we are now ready to estimate the fraction, from each visual grade, that the grading machine will be able to qualify for each MSR grade.

This estimate is also made in a rather arbitrary and graphic manner from the E distribution histograms that have been prepared (figs. 14-16, combined values). The philosophy applied here is that: (1) The E distribution histogram represents the stiffness content of the lumber that will be presented to the grading machine for sorting on a continuing basis; (2) the minimum average E requirements of all grades will have to be met simultaneously from the E distribution shown in the histogram; (3) at this point our estimating process is more concerned with "What is available?" than with grading machine behavior. (This assumes that machines can be adjusted or programmed to do the work demanded of them.) Our main focus in this estimate is to answer "What is available?" and defers the question of "How do we get it?" to a later date.

The suggested procedure for making the estimate from the histograms is to start with the highest grade and work downward to the lowest grade. This assumes it is desirable to obtain the best possible yield of high grades, allowing any compromise in yield to fall to the lower grades. This may not always be the most desirable position

with respect to economic return and total MSR grade yield, but it will demonstrate how to make the estimates.

Applying this idea to the Select Structural 2 x 4's (fig. 14), the results are shown in figure 19.

First Step--What fraction of the Select Structural will average the 2.01E that has been selected to satisfy the MSR grade strength requirements? We can reason like this: All the lumber shown as being in the 2.0 and higher E classes will satisfy this demand. Now, how much of the lumber from the lower E classes can we include? In the histogram we note that approximately 8 percent of the total expected lumber supply represented by the 103 pieces falls in the 2.1, 2.2, and 2.3 E classes; we can therefore conservatively estimate that 6 percent from the 1.9E class can also be included to produce a resultant 2.01E average. Thus, we draw an outline as shown, taking all 2.0 and higher E classes and 6 percent (6 pieces) from the 1.9E class. Adding all percentages of the histogram included in this 2.0E grade outline results in approximately 20 percent of the Select Structural 2 x 4's being included in the 2400f-2.0E MSR grade.

Second Step--From the lumber remaining after the 2.0E grade material has been removed, what fraction is available to provide an average E of 1.82 for the 2100f-1.8E grade? We can reason that all of the actual 1.8E class and the 12 percent (12 pieces in this example) remaining in the 1.9E class is available. The percent of the 1.7E class then can be calculated to be 12 percent to provide the average of 1.82E desired. Algebraically this is as follows in this example:

$$(12 \text{ pieces})\ (1.9E) + (14 \text{ pieces})\ (1.8E) + (X \text{ pieces})\ (1.7E) =$$

$$(12 + 14 + X)\ (1.8E)$$

$$22.8 + 25.2 + (1.7\ X) = 46.8 + 1.8\ X$$

$$0.1\ X = 1.2$$

$$X = 12 \text{ pieces of the } 1.7E \text{ class}$$

However, conservatism again prevailed and for estimating purposes, it was decided to use 6 percent (or 6 pieces) from the 1.7E class as an estimate for inclusion in the 1.8E grade. Our estimate is that 32 percent of the Select Structural 2 x 4's are qualified by the machine grading process for inclusion in the 2100f-1.8E MSR grade.

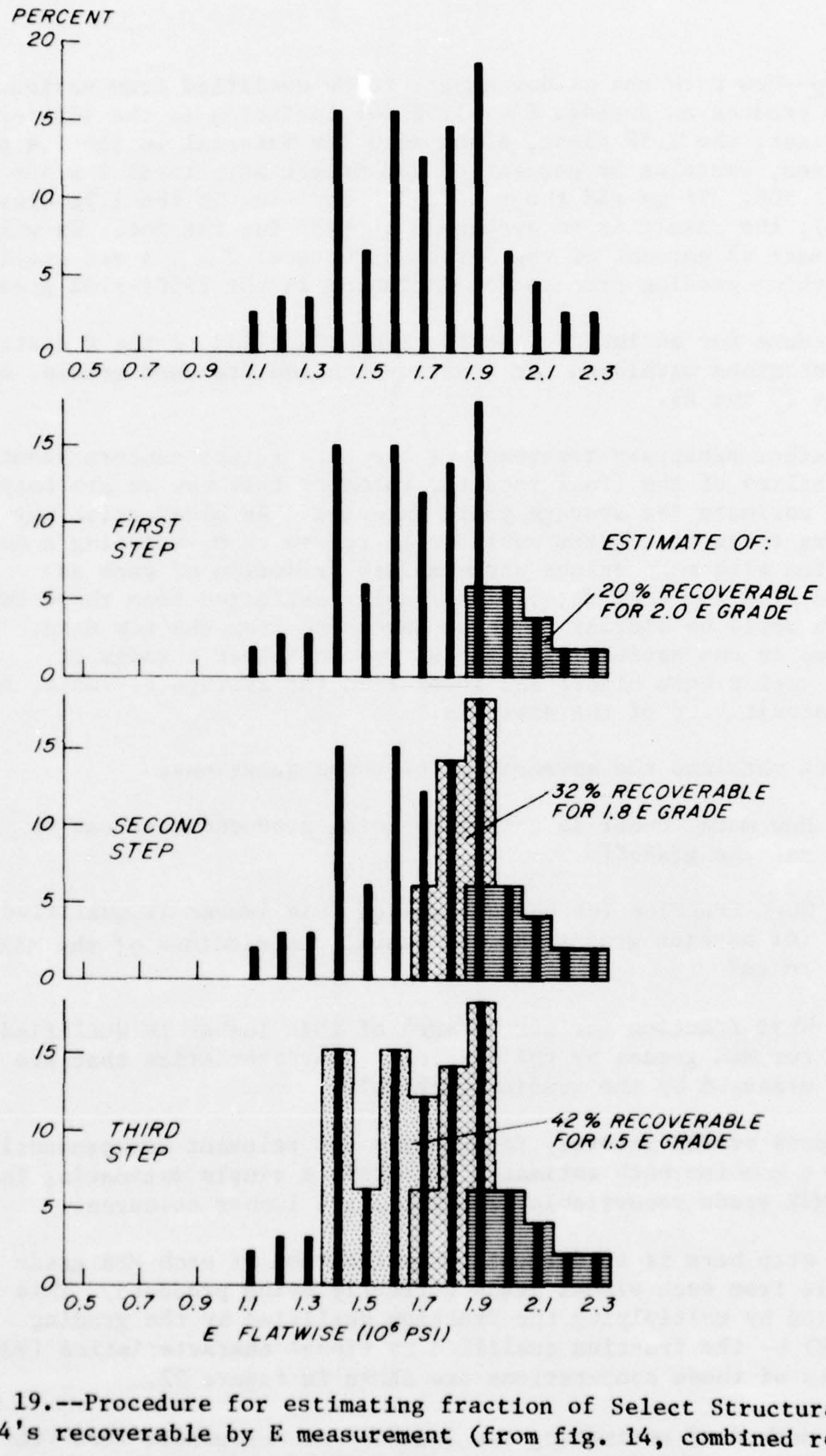

Figure 19.--Procedure for estimating fraction of Select Structural Grade 2 x 4's recoverable by E measurement (from fig. 14, combined result).

(M 143 916)

Third Step--How much can we now expect to be qualified from various E levels to produce an average E of 1.52 for inclusion in the 1650f-1.5E grade? First, the 1.5E class, along with the material in the 1.4 and 1.6E classes, contains 36 percent of the Select Structural 2 x 4's and averages 1.50E. If we add the 6 percent remaining in the 1.7E class (6 pieces), the result is an average E of 1.53 for the lot. We will thus estimate 42 percent of the Select Structural 2 x 4's are qualified by the machine grading process for inclusion in the 1650f-1.5E grade.

This procedure for estimating should also be applied to the E distribution histograms developed for Construction and Standard grades, as in figures 20 and 21.

If this rather arbitrary treatment of the data raises concern about the reliability of the final results, remember that now we are only trying to estimate the average yield expected. An alternative way of treating these histograms would be to redraw them, assuming a normal distribution with mean values and standard deviation of each as determined from the test data. The results estimated from these revised histograms would be similar to those developed from the raw data. As a last step in the estimating process, we can select a range of estimated yields both higher and lower than the average estimate, to test the sensitivity of the analysis.

We have now obtained the answers to the three questions:

(1) How much lumber is currently being produced that can be machine graded?

(2) What fraction (or percentage) of this lumber is qualified for machine grading by the visual restrictions of the MSR rules?

(3) What fraction (or percentage) of this lumber is qualified for MSR grades by the stiffness characteristics that are measured by the grading machine?

But stiffness or VQL recovery figures are not relevant independently. Now we must combine both estimates to obtain a single estimating factor for each MSR grade recoverable from the 2 x 4 lumber resource.

The first step here is to determine the fraction of each MSR grade recoverable from each visual grade currently being produced. This is accomplished by multiplying the fraction qualified by the grading machine (E) by the fraction qualified by visual characteristics (VQL). The results of these computations are shown in figure 22.

While the method of estimating the fraction of MSR grades from VQL-1 is reasonably straightforward, the method of determining the fraction

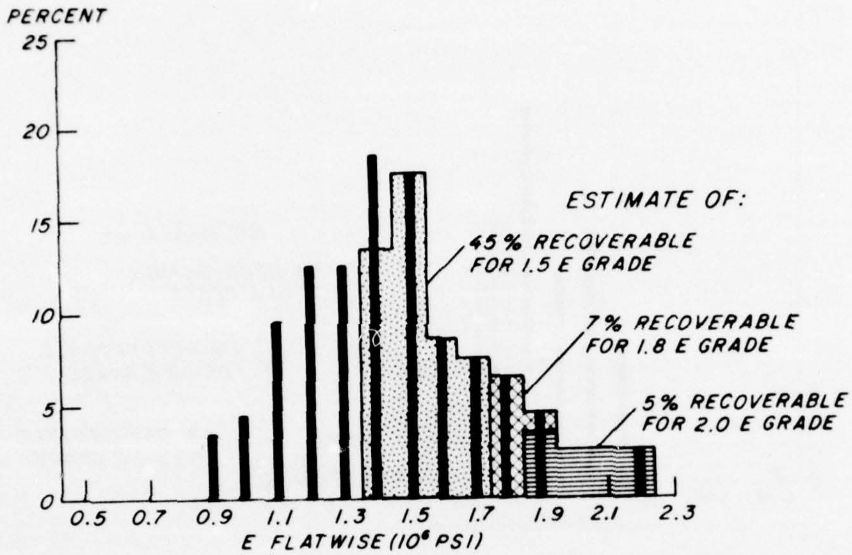

Figure 20.--Estimate of fraction of Construction Grade 2 x 4's recoverable by E measurement. (From fig. 15, combined, using procedures as in fig. 19.)

(M 143 914)

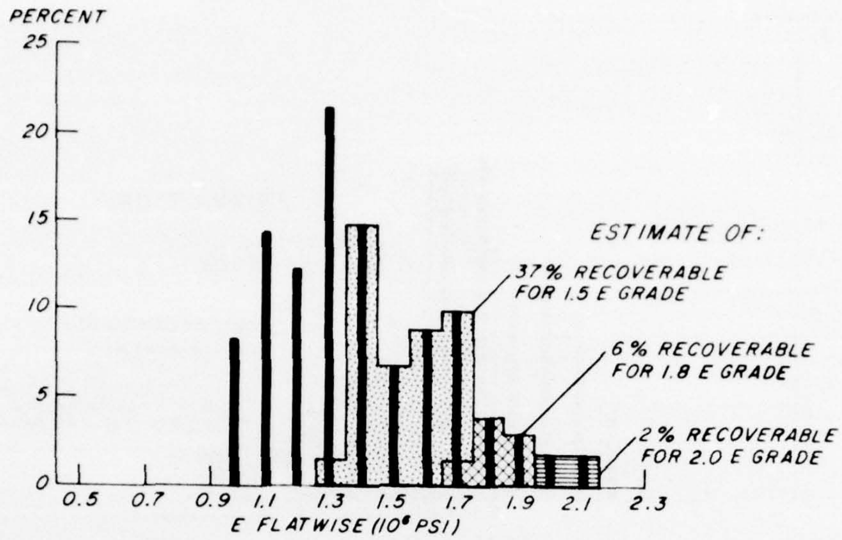

Figure 21.--Estimate of fraction of Standard Grade 2 x 4's recoverable by E measurement. (From fig. 16, combined, using procedures as in fig. 19.)

(M 143 919)

Visual Grade	MSR Grade	Fraction Qualified for MSR grade by: Machine E	Grader VQL-1	Grader VQL-2	Fraction of MSR Grade recoverable from visual grade
Select Structural	2400f-2.0E	0.20	0.97		0.19
	2100f-1.8E	.32	.97		.31
	1650f-1.5E	.42	.97		.44
		.94*		.03*	
Construction	2400f-2.0E	.05	.22		.01
	2100f-1.8E	.07	.22		.02
	1650f-1.5E	.45	.22		.26
		.57*		.28*	
Standard	2400f-2.0E	.02	.11		--
	2100f-1.8E	.06	.11		.01
	1650f-1.5E	.37	.11		.10
		.45*		.13*	

Figure 22.--Estimate of fraction recoverable--MSR grades from visual grades.

* Note: The fraction recoverable by E applied to VQL-2 is the sum of the fractions applicable to all three MSR grades when applied to VQL-1. This assumes that the actual distribution of E does not change with the different MSR-VQL within the visual grade of interest. This is not precisely true; the result is pessimistic with respect to yield of the higher grades and optimistic with respect to yield of the lower grades.

(M 144 545)

recoverable out of VQL-2 is not quite as obvious. In our example, the only MSR grade that can be made of MSR-VQL 2 is 1650f-1.5E. Therefore it is assumed that, based on E measurement, a fraction equal to the sum of the fractions applicable to all three MSR grades is recoverable. Then the total fraction of 1650f-1.5E recoverable is this number multiplied by the fraction of MSR-VQL 2 contained in the visual grade in question (fig. 22). Actually the VQL yields and E yields are not independent but experience has shown that the assumptions made above are suitable for a feasibility analysis.

Figure 23 illustrates the calculation of volumes of MSR grades recoverable from all the 2 x 4's being produced by the mill as a function of the visual grade output (from fig. 13) and MSR grade yield (from fig. 22). The rounded percentages from the fractions resulting are 2400f-2.0E, 2 percent; 2100f-1.8E, 3 percent; and 1650f-1.5E, 19 percent.

The assumption has been made that the mill will market both MSR and the traditional visual grades where the quantities warrant the practice. This may not be the final decision of the mill because this type of analysis has always exposed other alternatives for consideration. For purposes of this example, however, the proposed mix of visual and MSR grades is contrasted with the current product mix in figure 24. Of course, in the proposed product mix, the fractions of Select Structural, Construction, and Standard are adjusted downward from the fraction in the current product mix in accordance with the portion converted to MSR grades.

Figure 24 completes the objective of the analysis. It is now time to turn the data over to the marketing and production managers for economic evaluation.

This method of assessing the MSR production capability of a mill has general application to different product mixes. This versatility becomes an important feature, because production capability and economic evaluation are unique to each mill.

Nevertheless, it must be reemphasized that this is not a precise analytical method. It is an estimation technique developed over a series of actual mill evaluations. It is sufficiently accurate to aid management in predicting the potential product mix by introduction of MSR, primarily in the 2 x 4 and 2 x 6 medium-to-high strength categories.

Visual Grade	BF/MMBF 2 X 4 Pct	BF	MSR Grade	Fraction of MSR Grade recoverable from Visual Grade	Estimated Volume of MSR Grades Recoverable, BF/MMBF 2400/2.0	2100/1.8	1650/1.5
Select Structural	6	60,000	2400/2.0	0.19	11,500		
			2100/1.8	.31		18,600	
			1650/1.5	.44			26,400
Construction	55	550,000	2400/2.0	.01	5,500		
			2100/1.8	.02		11,000	
			1650/1.5	.26			143,000
Standard	22	220,000	2400/2.0	-			
			2100/1.8	.01		2,200	
			1650/1.5	.10			22,000
			Total		16,900	31,800	191,400
			Fraction of Total		.017	.032	.191

Figure 23.--Estimated MSR volume recoverable from 1 million board feet of 2 x 4's produced.

(M 144 543)

Grade	Current Product Mix Fraction	Current Product Mix BF/MMBF	Proposed Product Mix Fraction	Proposed Product Mix BF/MMBF
MSR 2400f - 2.0E			0.02	20,000
MSR 2100f - 1.8E			.03	30,000
MSR 1650f - 1.5E			.19	190,000
Select Structural	0.06	60,000	0*	
Construction	.55	550,000	.39	390,000
Standard	.22	220,000	.20	200,000
Utility	.13	130,000	.13	130,000
Economy	.04	40,000	.04	40,000

* Because Select Structural remaining after machine grading is less than 0.5 pct, assume it is included with Construction grade in Standard and Better grade mix.

Figure 24.--Estimates of the proportions of 2 x 4 product mix under the current visual and proposed visual plus MSR product mixes. Quantities shown are based on an assumed 1 million board feet of 2 x 4's produced.

(M 144 544)

III--MILL APPLICATION OF MSR[5]

If, after considering the previous portions, it appears some potential income can be gained by machine-grading, what will equipment cost? Will the net gain be attractive?

MSR Machines

A variety of machines are available for mechanical stress rating of lumber. Some are high production "in line" machines that can be used directly with a high-speed planer so all the input to the planer passes through the stress rating machine. By contrast, others are "out of line" machines or machines which can be operated at 3 to 10 boards per minute. Mill locations of MSR devices, known to be operating in the United States and Canada, are listed in Appendix B.

High-Speed Machines

Examples of the high-speed production machines are the Continuous Lumber Tester, (CLT-1) developed originally by Potlatch Forests Inc.; the Stress-O-Matic (SOM) developed by the Western Pine Association; and the Computermatic, which is manufactured in Australia by Plessey Machine Company. The two production machines presently in use in the United States are the CLT-1 and the SOM. Both are adaptable to an in line operation. They are both electro-mechanical in design; both measure the board stiffness by continuously, mechanically flexing the board over a set of rolls as the board passes flatwise through the machine.

In the CLT-1, the stiffness of each piece is measured by determining the force necessary to deflect the piece flatwise a fixed amount in both the UP and DOWN directions (fig. 25). The machine continuously monitors for "low point" (the lowest stiffness) in the piece. This reading is stored in the computer low-point storage bank. The machine simultaneously measures the "force" repetitively during board travel and averages these readings to obtain an "average" E measurement. These readings also are stored. The machine has a dual decision-making process. Final E category is determined by both low-point and average criteria.

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[5] Presented in part by Gerald W. Crow, Crow Engineering Co. at the 1975 Forest Products Research Society annual meeting, Portland, Oreg..

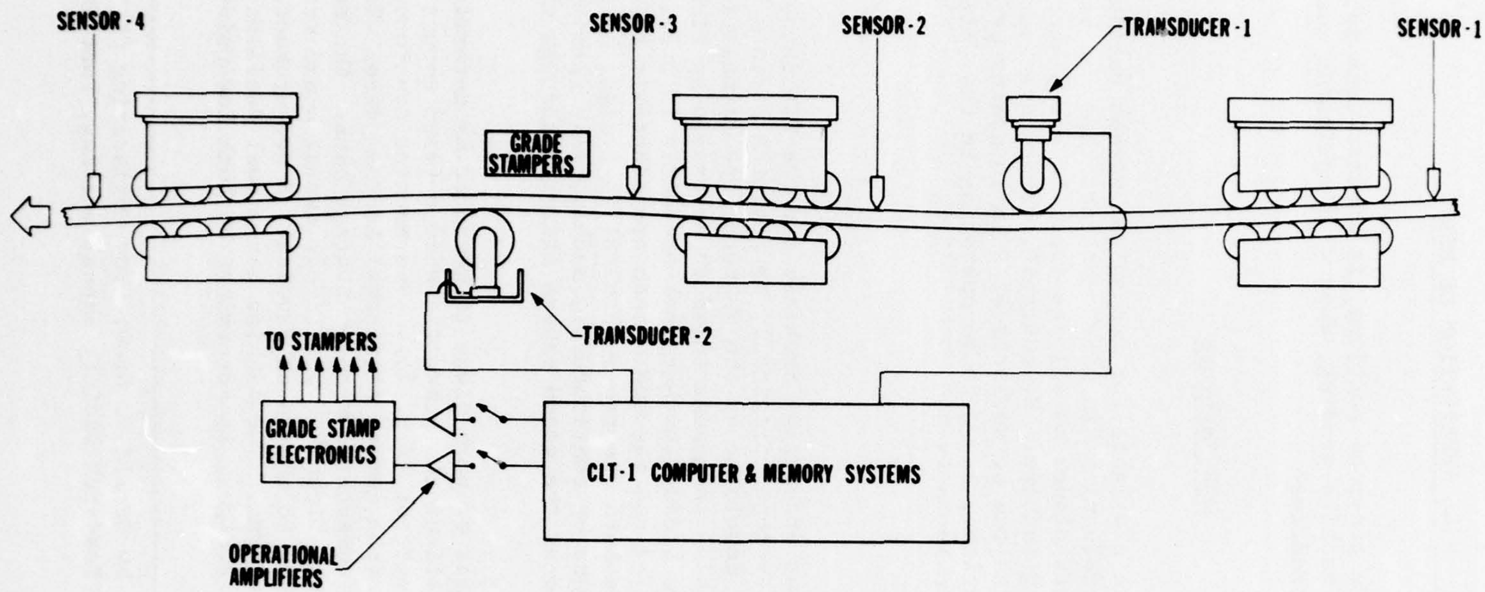

Figure 25.--Illustration of the operation of the CLT-1 machine.

(M 143 812)

The machine computer is programmed for the particular dimensions of material being graded. The maximum feed rate of the CLT-1 is 1,000 lineal feet per minute, but realistic production rates have varied from 500 to 800 feet.

In the Stress-O-Matic (SOM) the stiffness of each piece is measured by applying a fixed load over a 4-ft span on a flat face in one direction only. If the deflection under the load exceeds a preset value, the applied load is reduced. The process continues until the highest load is reached that will not exceed the preset deflection limit. This load identifies the minimum stiffness portion of the piece (fig. 26). As with all in line machines currently on the market, the SOM has undergone several model changes. The maximum feed rate for the present SOM is 600 lineal feet per minute, and many machines are operating at 400 feet.

The Computermatic machine differs from the CLT-1 and the Stress-O-Matic in that the board is fed through the machine on the narrow edge (fig. 27). The piece is deflected at spans of 3 feet, with each span overlapping by 6 inches. The grade for each 6-inch section is stored in the machine computer. The machine is provided with a bank of five color sprays; the grade of each span tested can be marked on the piece by a pulse of color stain. As the piece leaves the machine, a longer color stain, which corresponds to the low-point reading, is applied to the piece. Cards program the computer for each type and cross section of material being graded.

The feeding of material into the Computermatic is very critical. The piece must be on edge, accelerated to the machine speed and held stable as it passes through the machine. The maximum production rate of the Computermatic is 500 lineal feet per minute. No Computermatics are operating on a production basis in the United States but this is a common machine in England, Europe, New Zealand, and Australia.

All three high-speed machines have been accepted for stress-grading under the provisions of the American Lumber Standard. All can be arranged so that all material going through the planer passes through the machine. However, in most installations the machine is installed out-of-line so that only a selected amount of the material going through the planer passes through the stress tester. This is particularly important if the mill has a high-speed planer; the speed limitations of the Stress-O-Matic and the Computermatic require installations be out-of-line with the planer.

Low-Speed Machines

Examples of grading or specialty machines in which the lumber throughput is slower are the E-Computer (Irvington-Moore), the Stress-Wave

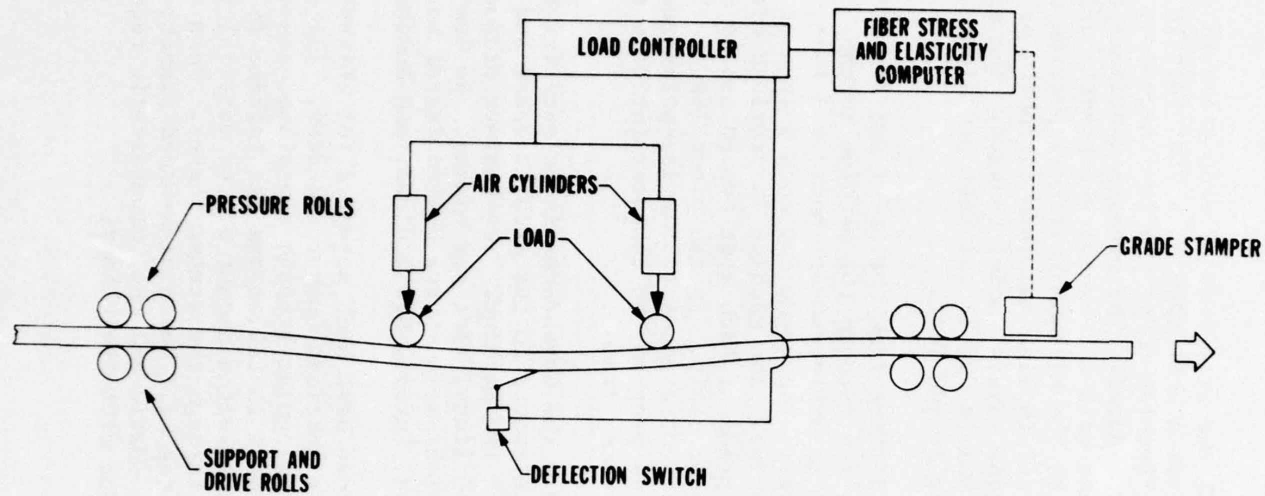

Figure 26.--Illustration of the operation of the SOM.

(M 143 811)

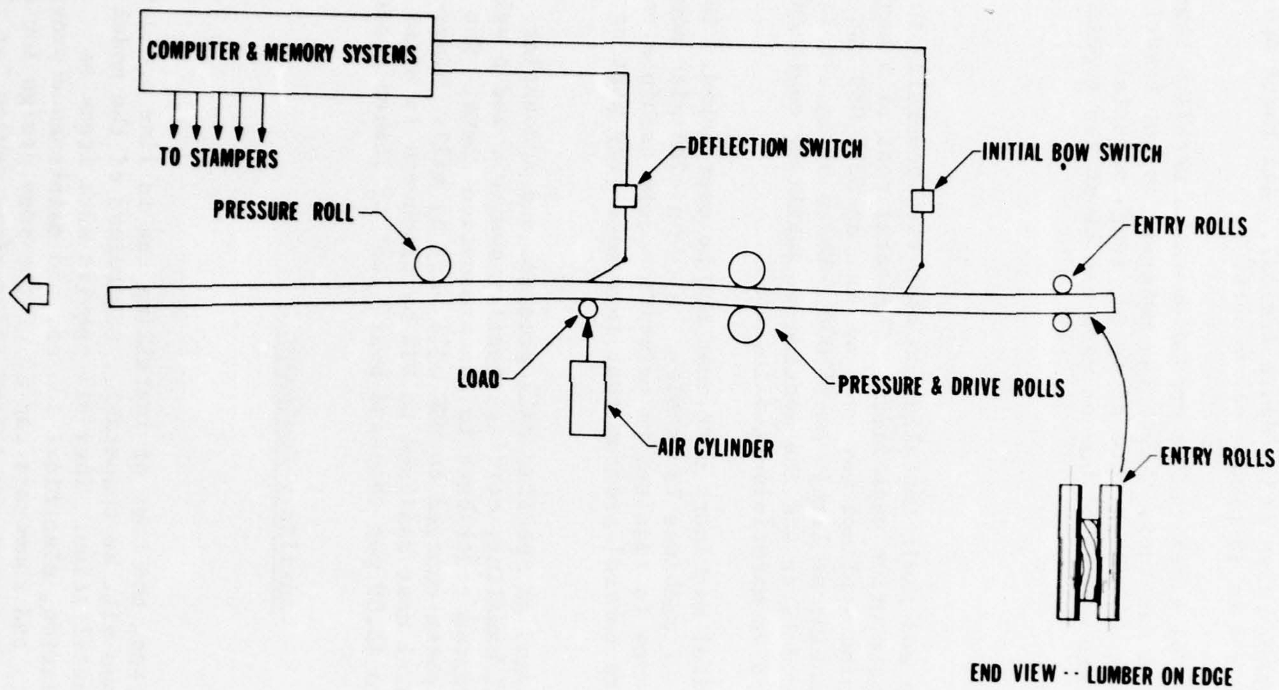

Figure 27.--Illustration of the Computermatic machine.

(M 143 819)

MOE computer (Porter Engineering Co., British Columbia), and the TRU Timber Grader (Compressor Valve Ltd., South Africa). All three are capable of grading from 4 to 10 pieces per minute.

A wider range of material sizes can be graded on these machines than on the three high-speed machines. Since the material is not traveling through the machine at a high rate of speed, rough material or material with a moderate amount of bow or warp can be stress graded with good results.

Costs

The price of machines and their installation cost vary generally in proportion to their production capability. The total cost of a high-speed arrangement behind a planer may cost as much as $250,000 and a slower manual-type machine as little as $5,000. Costs of industrial machines are summarized later and the section on auxiliary equipment will permit estimation of materials-handling costs.

Costs other than capital machinery cost must not be overlooked. The electronic circuitry of machines is complex. A technician with some knowledge of electronics is required to maintain modern machines and to monitor the quality control program that is a necessary part of MSR.

Costs, of course, depend on specific mill programs and accounting. For example, material handling, sorting, quality control, and a well-controlled drying program contribute to the production costs. The proportion of these costs charged to MSR will vary by mill. Nevertheless, the real total cost assigned to MSR by producers is often described as $2.00 to $5.00 per thousand board feet of lumber graded.

Auxiliary Equipment

Lumber Handling

For assumption purposes, the cost of installing the in line production stress-rating machines will be comparable, regardless of the model for a planer mill installation. They all require such items as vibration-free foundation, electrical source, and maintenance provisions. The related transfers and conveyors can be of the same design for any machine, with the exception of the infeed and outfeed device for the Computermatic because the lumber is handled on edge. The number of these peripheral systems and their specific design will depend on the material flow pattern chosen.

All of the machines, if installed out of line with the planer, must have an infeed table that will deliver individual pieces to the machine at a speed compatible with the machine operating speed. This involves a singulator for feeding one piece at a time onto an accelerator table to get the piece up to machine speed.

For the CLT-1 and the Stress-O-Matic, the piece is fed flatwise into the machine. The accelerator system is similar to a planer feed table. With the Computermatic, the piece is fed on edge into the machine, and the accelerator must hold the piece vertically without lateral movement. Boards with excessive warp, bow, or waney edges present a special problem to the Computermatic and should be by-passed.

The arrangement of the mechanical stress grading equipment in the mill usually depends upon the existing mill flow and the production requirements. Figures 28-35 illustrate arrangements of MSR machines and essential auxillary equipment and will permit estimating the specific capital investment and installation costs. These sketches are based on currently operating MSR installations.

If only part of the material that is run through the planer is to be machine stress-rated, a flow plan similar to those in figures 28 to 34 is used. In some instances it is practical to provide an infeed to the stress tester without going through the planer. Such an arrangement is shown on figures 30 and 31.

If all the material that is run through the planer is to be mechanically stress rated, the stress grading machine can be directly in line with the planer (fig. 35). In this case, if the planer speed is to be over 600 ft. per minute, the machine must be a CLT-1. This type of an installation is the least expensive because of the limited number of transfers and conveyors, but a machine by-pass and a retrim capability is desired to provide flexibility.

In all cases, it is necessary to visually check-grade the lumber after the stress rating machine. Provisions for this step vary with mechanical arrangements as shown in the sketches.

Quality Control

The successful and profitable utilization of a mechanical stress-rating machine in a mill depends in a large part on how committed the mill is to a quality control program. This program should start with the log breakdown into lumber and follow through all phases of the operation.

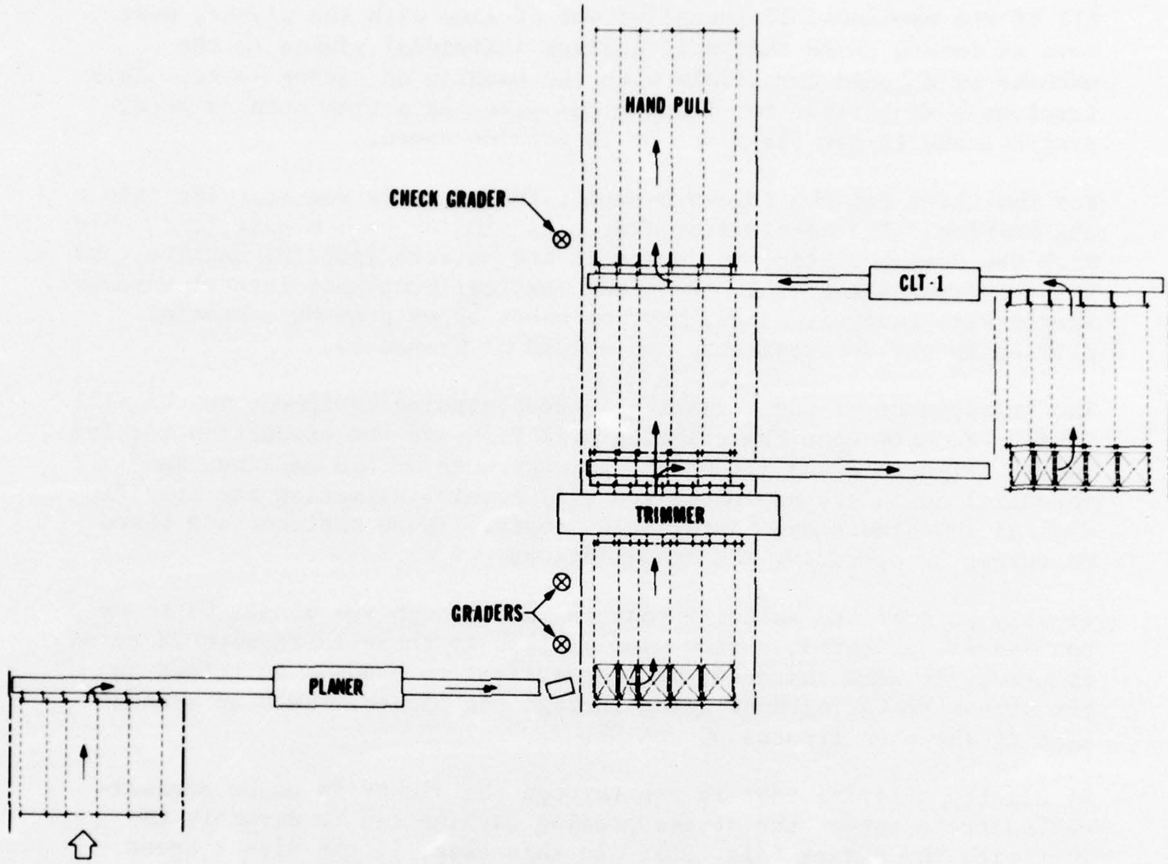

Figure 28.--A basic planing mill arrangement for machine grading. The visual graders designate the pieces to be routed through the CLT grading machine. A check grader follows the machine grading and trimming operation to assure the correct grade output. Normally only a portion of the lumber passes through the grading machine.

(M 143 813)

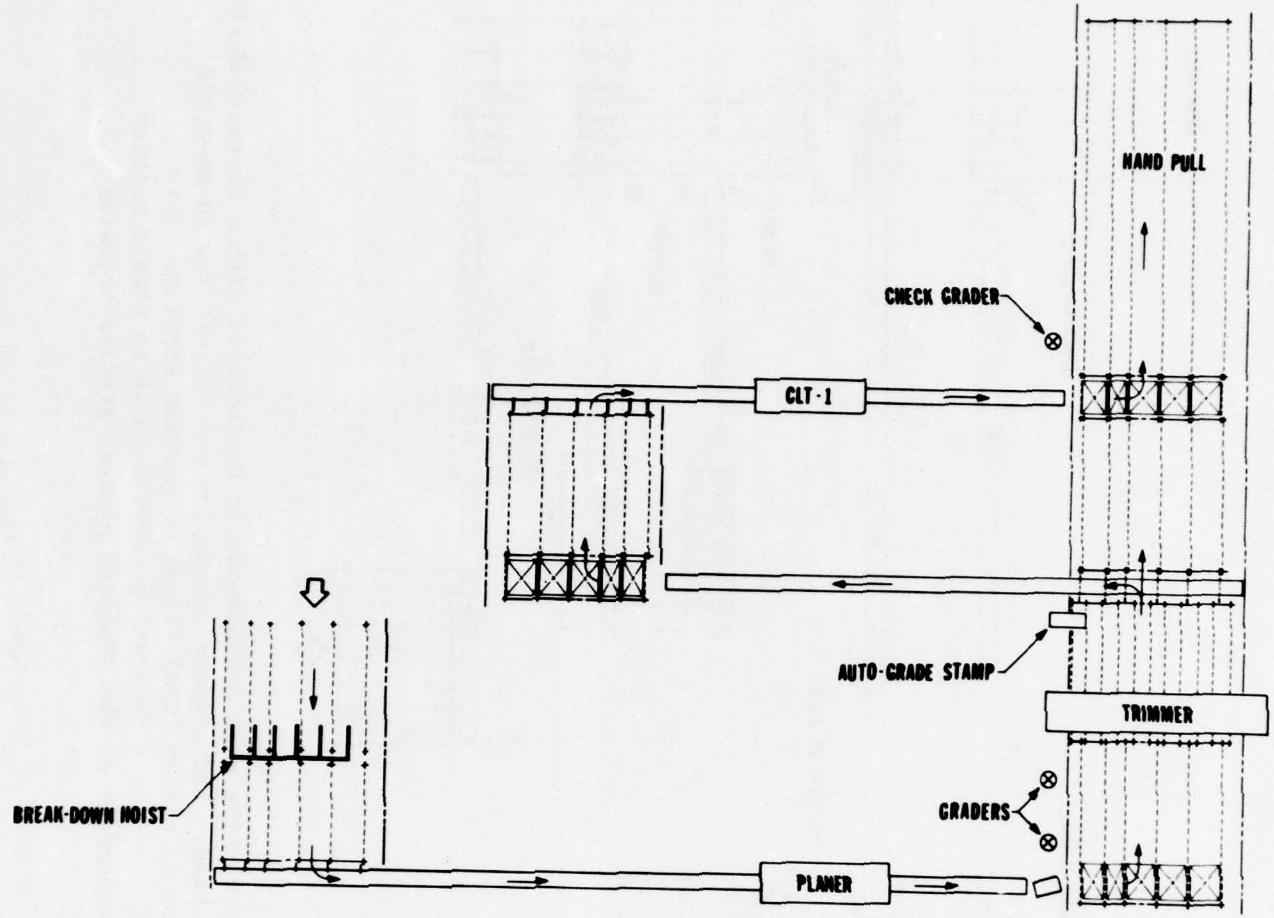

Figure 29.--A mill grading arrangement modified from that of figure 28 to incorporate an auto grading-trimming station which also controls the lumber to be routed to the CLT-1.

(M 143 816)

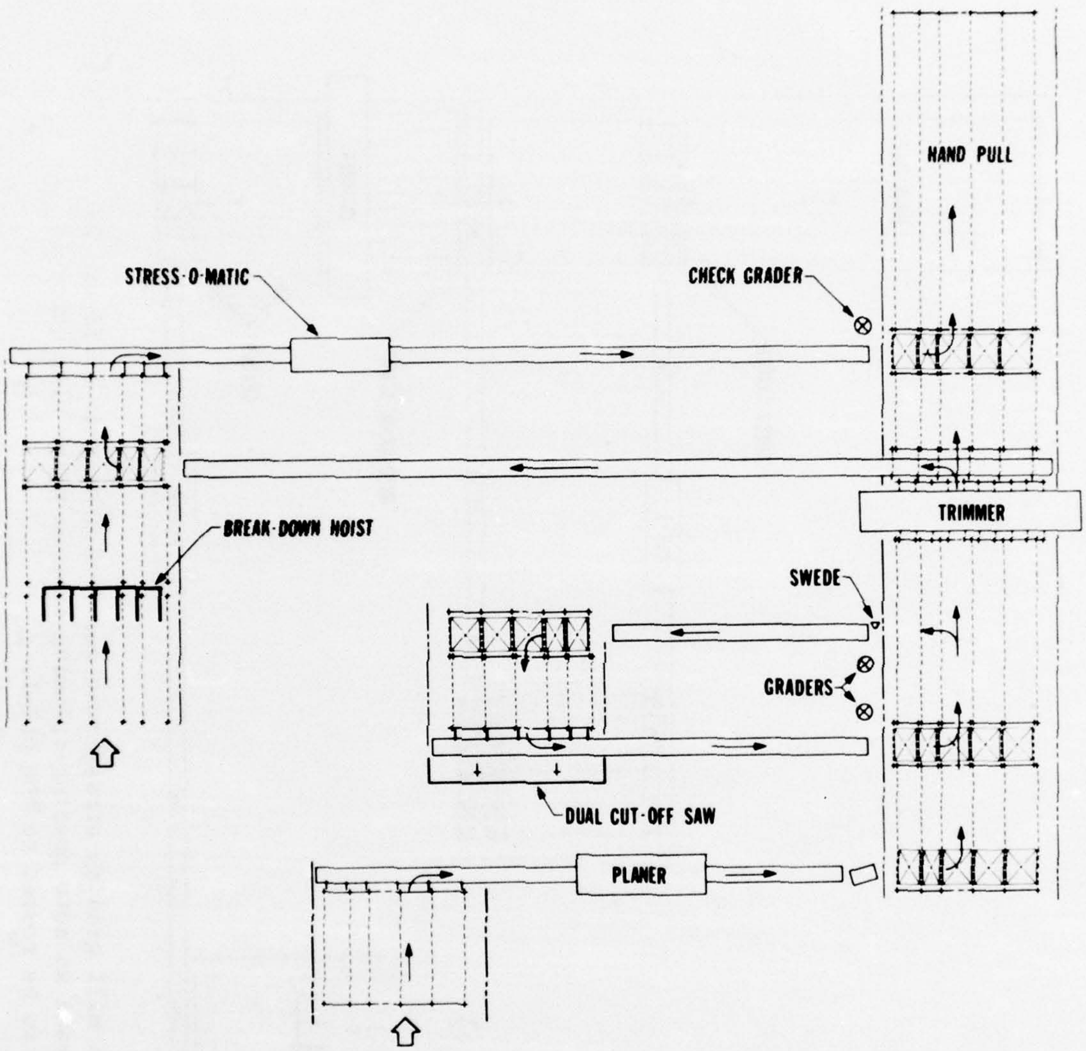

Figure 30.--A planing mill arrangement in conjunction with a Stress-O-Matic grading machine. The graders can employ the cut-off saw to up-grade lumber prior to either final visual or machine grading. This arrangement includes a separate breakdown hoist to permit machine grading independent of the standard planing-grading-trimming operation.

(M 143 814)

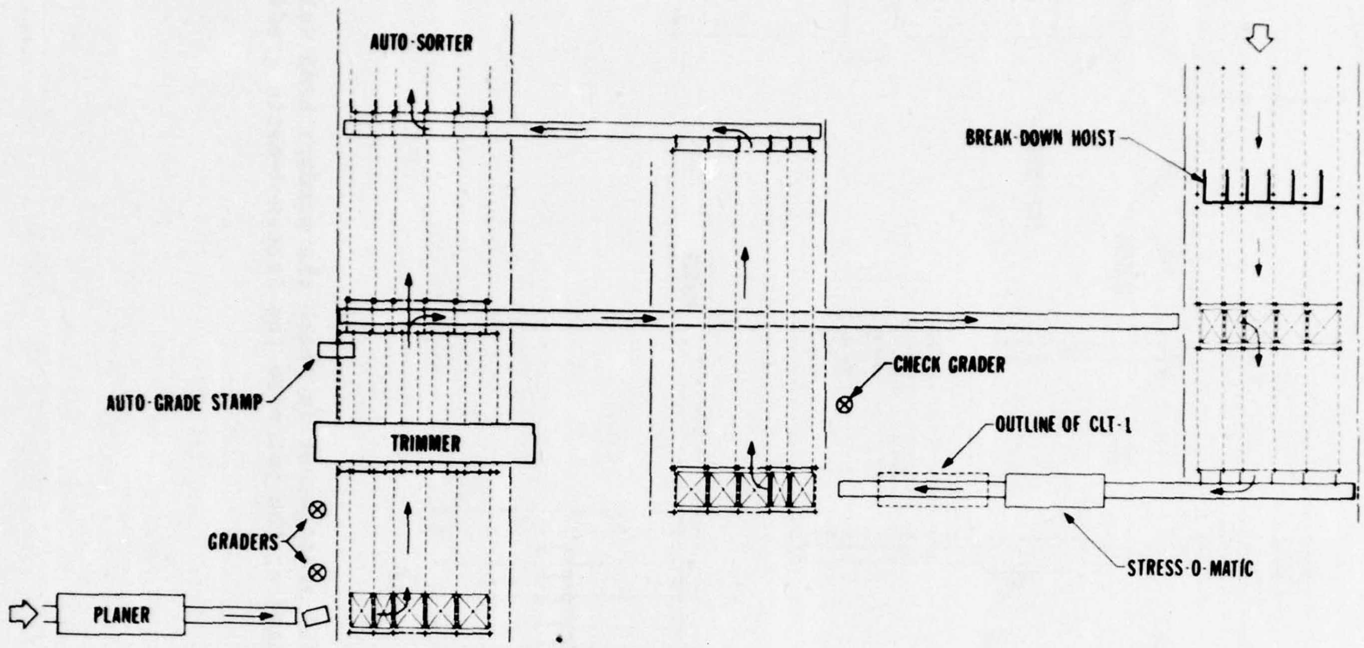

Figure 31.--A Stress-O-Matic grading operation in conjunction with automatic grading and trimming and an auto-sorter. A separate breakdown hoist adds flexibility to the installation. Provision is made for a CLT if desired at a later date.

(M 143 815)

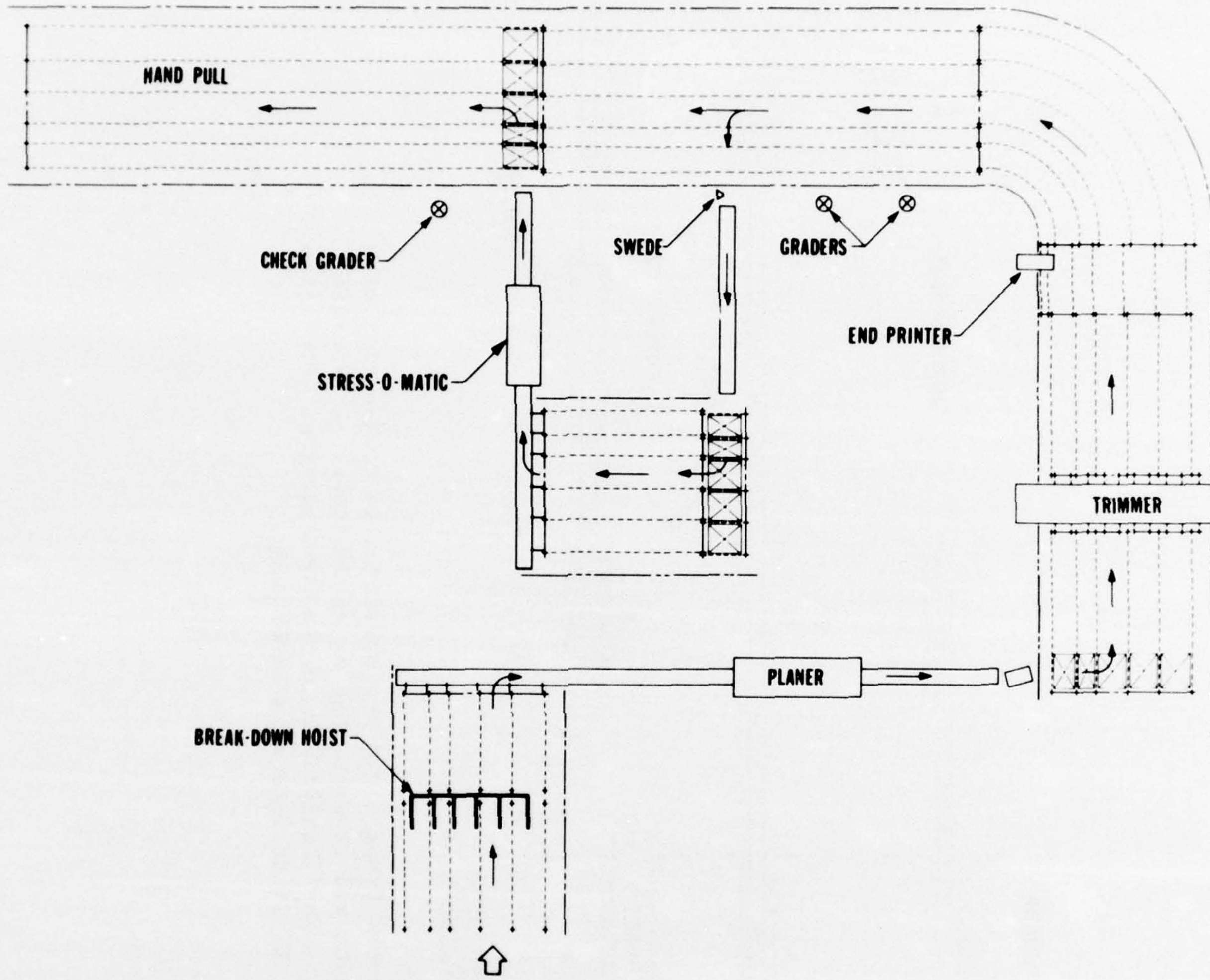

Figure 32.--A planing mill arrangement in which the graders hand select those pieces to be routed by the swede to the Stress-O-Matic grading machine.

(M 143 817)

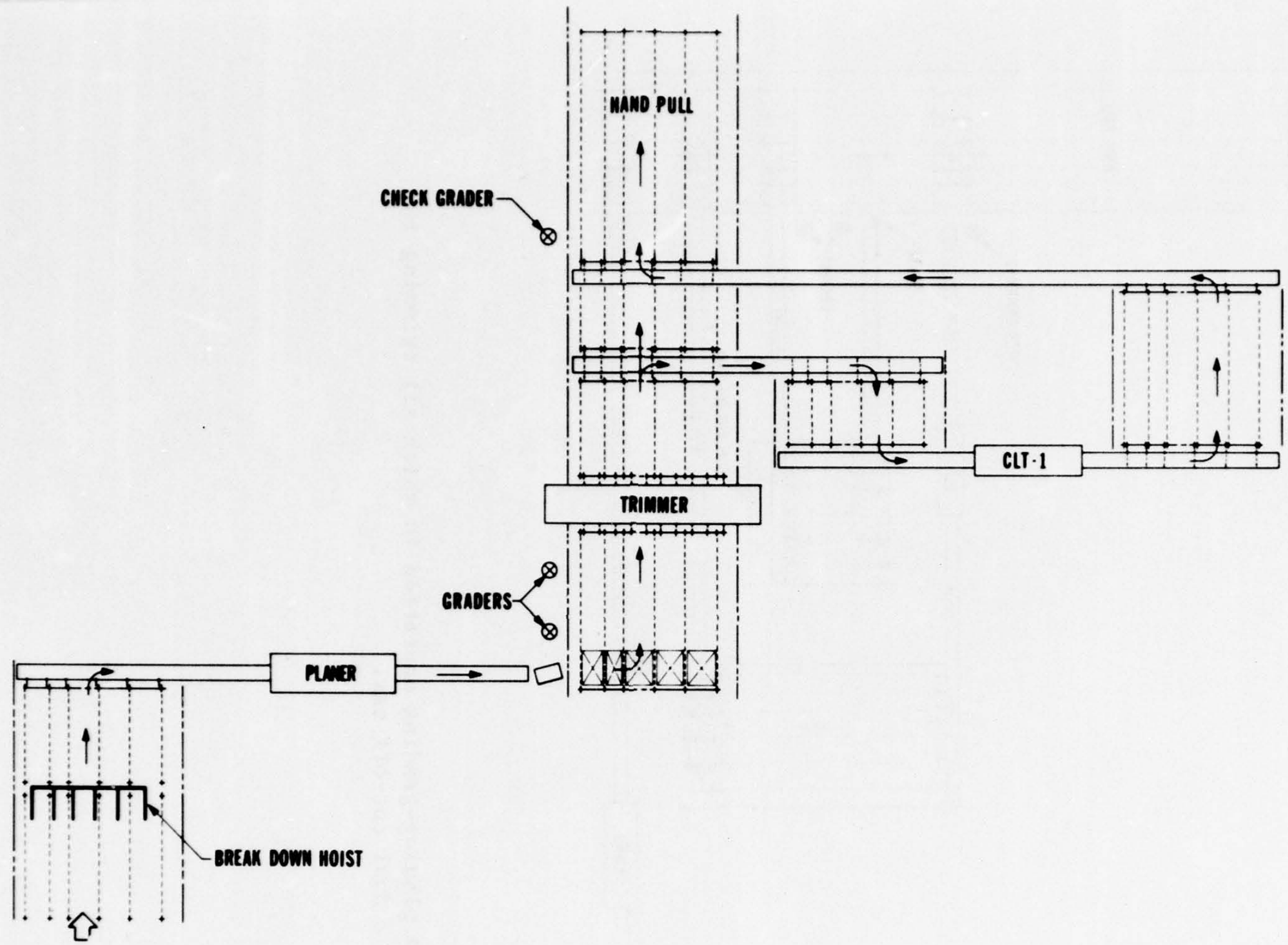

Figure 33.--A grading arrangement illustrating a variation in equipment for routing lumber from the dry chain through the grading machine and back to the check grader.

(M 143 820)

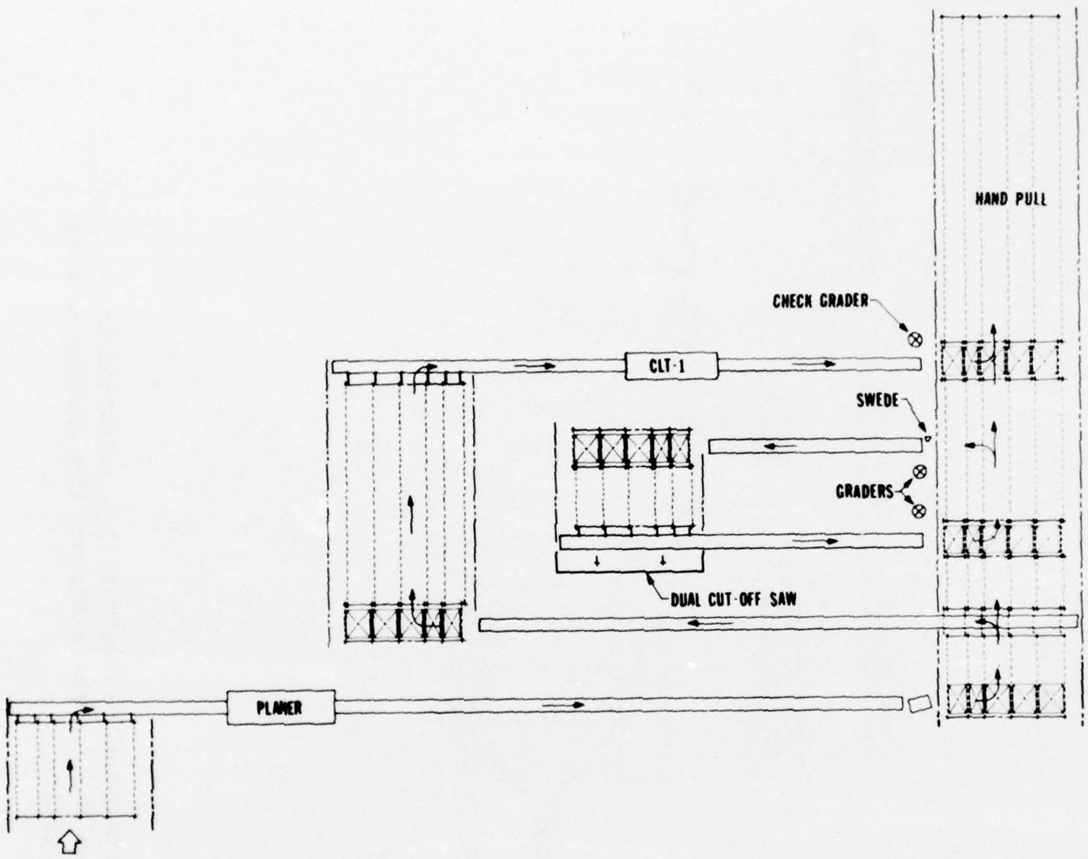

Figure 34.--A planing-grading operation in which all trimming is handled by a dual cut-off saw.

(M 143 821)

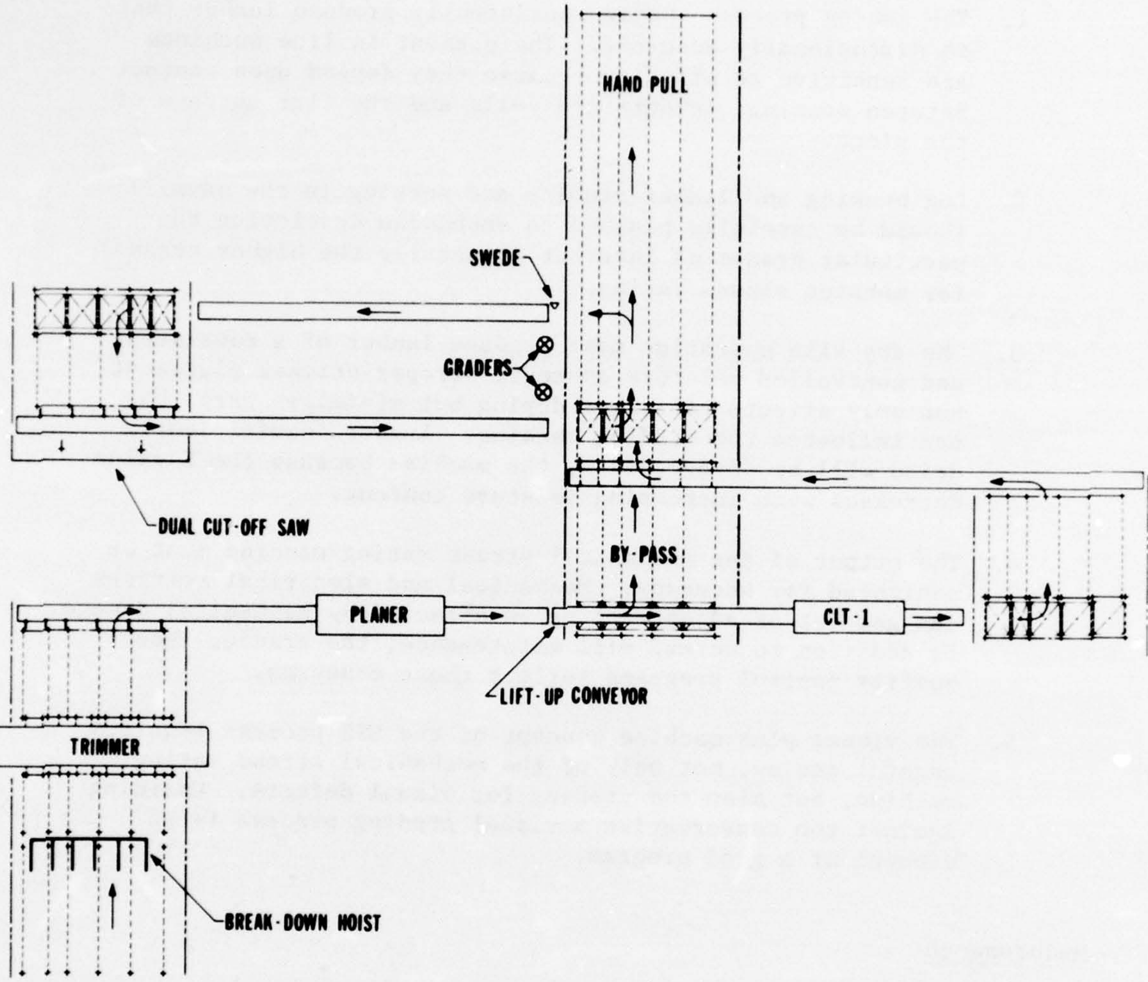

Figure 35.--A planing mill arrangement in which all lumber is trimmed prior to planing and in which all lumber is passed through the grading machine as the standard procedure. The by-pass permits mill operation with visual grading if the CLT-1 is out of operation.

(M 143 818)

1. The sawing process should consistently produce lumber that is dimensionally accurate. The present in line machines are sensitive to off-size because they depend upon contact between sensing elements and rolls and the flat surface of the piece.

2. Log bucking and lumber grading and sorting in the sawmill should be carefully planned to emphasize developing the particular grades of interest (generally the higher grades) for machine stress rating.

3. The dry kiln operation must produce lumber of a consistent and controlled moisture content. Proper sticker placement not only affects efficient drying but minimizes warp that can influence the grading machine. Lumber insufficiently dried will be downgraded by the machine because the E value decreases with increasing moisture content.

4. The output of the mechanical stress rating machine must be monitored for accuracy. Mechanical and electrical settings can get out of adjustment or be affected by mechanical damage. In addition to normal mill maintenance, the grading agency quality control programs reflect these concerns.

5. The visual plus machine concept of the MSR process requires careful review, not only of the mechanical stress rating machine, but also the grading for visual defects. Guarding against too conservative a visual grading process is an element of a good program.

Maintenance

Routine machine maintenance on MSR equipment is important. Although recent developments reduce problems on some machines, this equipment is generally sensitive to such things as temperature, humidity, vibration, and noise.

Any mechanism operating at more than 400 ft. per min. in a mill environment has problems with bearing life, belt life, etc. Guards, shields, and other protective devices should be hinged or otherwise built to encourage routine maintenance and inspection of machine components.

Most stress testers, and particularly those that are mounted in line, are complex electro-mechanical devices. An in line arrangement that is not functioning properly loses production time. Anyone consid-

ering the installation of a mechanical stress grader should also consider having a qualified technician to service and maintain it. This person can also run the static test sampling and keep grading agency records.

Certain optional and calibration trouble-shooting equipment, such as oscilloscopes, may also be desirable. Obviously the test equipment must also be kept in good calibration and repair.

Because most deflection machines use the principle of a load cell or transducer to indicate stiffness, any interfering vibrations will appear as transducer output signals. This can be overcome by (1) surfacing lumber to close tolerances for finish, (2) isolating vibrations, and (3) using special electronic filter circuits. All practical efforts should be made to support the equipment on dynamic shock pads and minimize internal machinery vibrations. This will lead to more accurate measurements and longer equipment life.

One other precaution would be to regulate temperature, humidity, and dust in the vicinity of the electronic equipment. This is usually done by housing as much equipment as possible in a temperature-controlled room and filtering out dust and contaminated air. Temperature control has been shown particularly valuable where seasonal extremes are severe and where daily temperature variation commonly exceeds 25-30° F during the operating period.

Spare parts on hand will significantly minimize lost production. Fortunately, much of the electronic circuitry of the MSR devices is built with plug-in printed circuitry. With spare circuit boards on hand, it is not necessary to completely isolate a problem but merely to determine which part of the circuit is affected and replace that particular board. Repairs can then be made at the technician's convenience.

With stress graders, as with other equipment, routine maintenance and inspection doesn't cost--it pays.

Associated Concerns

Mill Flow

As figures 28-35 indicate, many arrangements are possible. The most popular arrangement probably is with the stress grader out-of-line and taking only selected grades or species.

An alternative arrangement is to establish a separate grading facility. This could be a grading station independent of the planing mill (perhaps

located at the shipping shed or in some other convenient location). Selected loads could be brought to the facility, then graded and returned. This arrangement allows use of the stress grader on an occasional basis without disturbing the main mill flow. Specialty manufacturers might prefer a separate grading station as it allows them to purchase selected grades from other mills and merely upgrade the material for its intended use.

Drying

Lumber drying is clearly connected with all types of grading and is particularly important in mechanical stress rating. Both stiffness and strength are affected by moisture content. Wood increases in stiffness and strength as it dries.

Loose knots, checks, honeycomb, warp, and collapse are other results of unequal shrinkage that can affect strength. Still other seasoning degrade may primarily affect appearance rather than strength. Obviously, suitable drying schedules and uniform moisture content are requirements for any stress grading operation.

Commercial Machines

To facilitate cost estimates and planning, the grading machines commercially available in the United States and Canada were surveyed for purchase price, operating principles, speed, product, size range, and installation requirements. Information was obtained and compiled from manufacturers and users. While material herein can never be completely up to date, it should serve as a starting point for an individual mill to make its specific investigations.[6] For detailed feasibility studies, mills should conduct their own inquiries to obtain up-to-date specific information.

Continuous Lumber Tester (CLT-1) (fig. 36)

Manufactured by:	Machine Cost: (less peripheral equipment)
Irvington-Moore P.O. Box 23038 Portland, Oreg. 97223	$90,000

Operating Principles:

Pieces of lumber are fed into the machine flatwise in a longitudinal direction. The individual piece is continuously deflected a given amount by powered rolls in both the UP and DOWN direction. The amount of force required to reach this given deflection is a measure of the stiffness of the piece. The stiffness is electronically recorded continuously along the length of each piece. As the lumber leaves the measuring section, the electronic computer determines the stiffness of the piece and actuates a stamp that automatically stamps the piece. This stamp can be the legal grade stamp or a symbol that corresponds to the stiffness rating. The machine has stamps and sufficient data banks for five grade classes. The machine measures both the average E and the lowest E of the piece. Measurements are made over a 4-ft span.

Operating Speed :

Maximum - 1,000 ft/min

[6] Costs and operating characteristics are based on 1975 estimates.

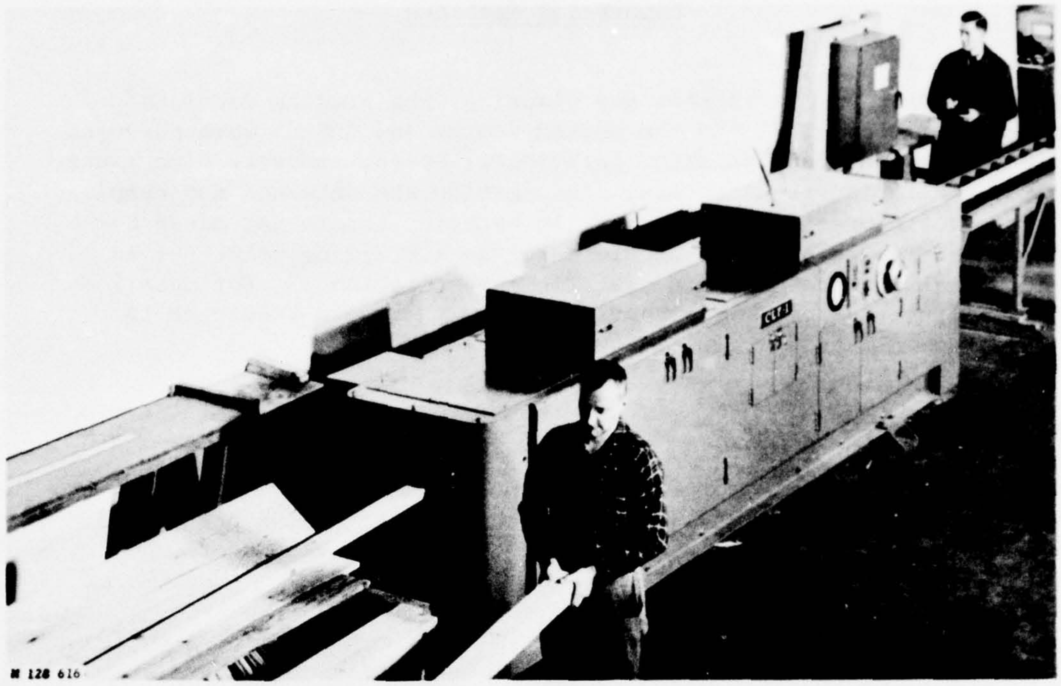

Figure 36.--CLT-1

(M 128 616)

Material Size (all nominal):

Thickness	- 2 in. min - 2 1/2 in. max
Width	- 4 in. min - 12 in. max
Length	- 8 ft min - 26 ft max

Installation Requirements:

Lumber must be fed into machine so that centerline of boards corresponds to the centerline of the lumber guide. Acceleration of the lumber to the machine speed is recommended by some users.

Machine must be mounted on a firm foundation free from vibration.

Air supply - 100 psi

Electrical service - 460V, 3 phase, 60 cycle.

Stress-O-Matic Lumber
Testing Machine (fig. 37)

Manufactured By:	Machine Cost: (less peripheral equipment)
Industrial Woodworking Machine Co., Inc. P.O. Box 1466 Garland, Texas 75040	$36,000

Operating Principle:

Pieces of lumber are fed into the machine flatwise in a longitudinal direction. The piece is continually deflected in one direction with a load applied through an air cylinder. If the highest initial load deflects the piece down far enough to trip a limit switch, air pressure is bled off the cylinder, thus decreasing the load until the limit switch is de-energized. As the piece leaves the machine, the highest load that would not deflect the piece the required amount to trip the limit switch is used to actuate a grade stamp corresponding to that stiffness. This stamp can be the legal grade stamp or a symbol that corresponds to the stiffness category. The machine has stamps and sufficient data banks for five grade classes.

Operating Speed:

Maximum - 600 ft/min

Material Size (nominal):

Thickness	- 2 in. min - 2 1/2 in. max
Width	- 4 in. min - 12 in. max
Length	- 8 ft min - 26 ft max

Installation Requirements:

Lumber must be fed into the machine so that the centerline of the piece corresponds to the centerline of the lumber guide.

Machine must be mounted on firm foundation free from vibration.

Air supply - 100 psi.

Electrical service - 460V, 3 phase, 60 cycle.

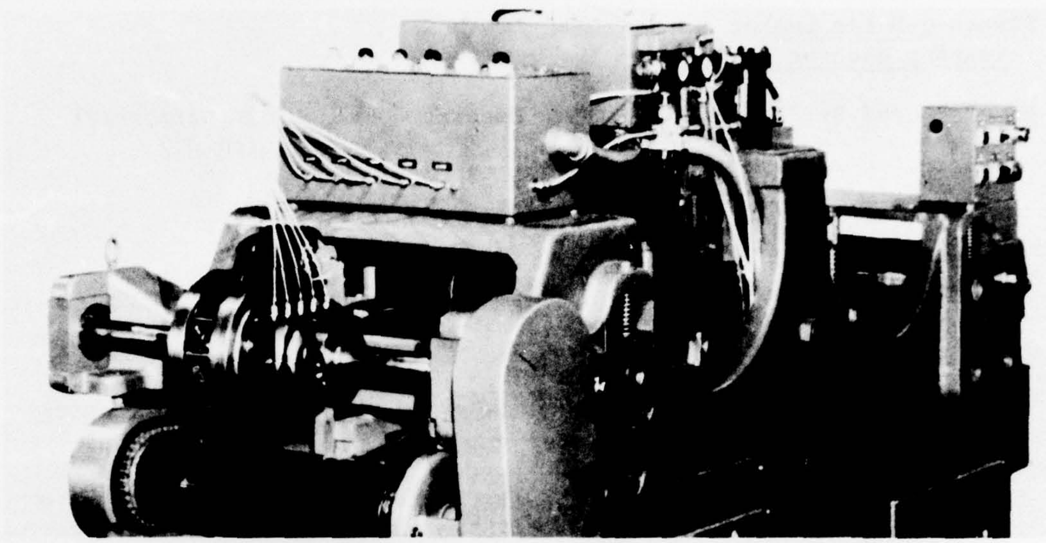

Figure 37.--Stressomatic.

(M 128 615)

Computermatic (fig. 38)

Manufactured By: Machine Cost: (less peripheral equipment)

Plessey Machine Co. - Australia $62,500

Exclusive Sales Agent:

Stetson-Ross
3200 First Ave. South
Seattle, Wash. 98134

Operating Principle:

Pieces of lumber are fed into the machine on edge in a longitudinal direction. The individual piece is continually deflected in its narrow dimension by a given load. The amount of deflection caused by this load is measured on 6-inch intervals throughout the length of the piece. The measurements are grouped into one of five classes. A color mark can be sprayed on the piece at each 6-inch interval that corresponds to the grade class. As the piece leaves the machine the lowest grade rating is computed and a paint spray corresponding to that low point rating is sprayed. Grade stamping options are available as well as computer-fed paper tape record.

Operating Speed:

Maximum - 500 ft/min.

Material Size (all nominal):

Thickness	- 1 to 3 in.
Width	- 2 to 12 in.
Length	- 8 to 26 ft.

Installation Requirements:

The feeding requirements of the machine are very critical. The lumber must be held on edge and be free from all lateral movement as it enters the feed rolls of the machine. Any whipping action will result in incorrect stress readings.

Machine must be mounted on firm foundation free from vibration.

Air supply - 100 psi

Electrical service - 460V, 3 phase, 60 cycle.

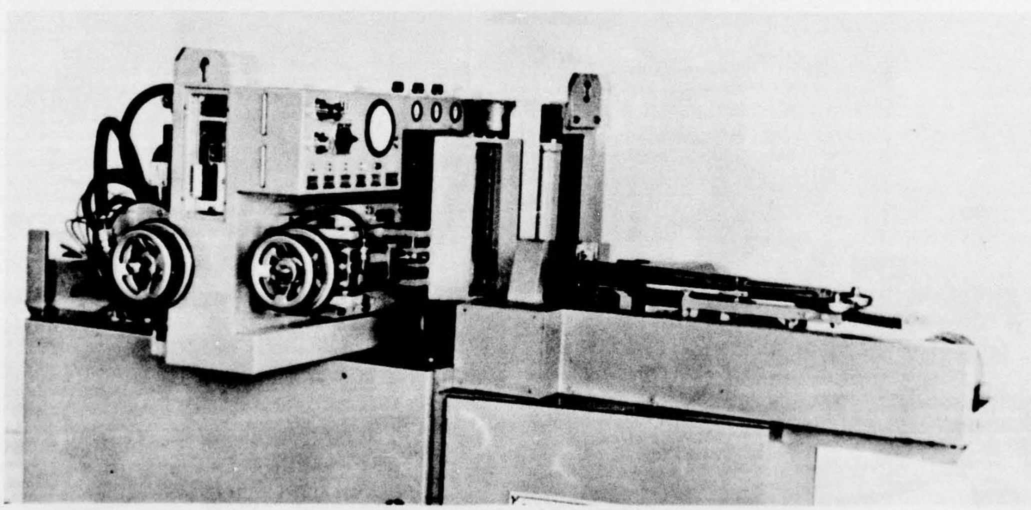

Figure 38.--Computermatic.

(M 143 875)

TRU Timber Grader (fig. 39)

Manufactured by: Machine Cost: $5,000

Compressor Valves Limited
P.O. Box 3794
Alrode, South Africa

Operating Principle:

Lumber is inserted between a set of fixed rollers and a set of weighted rollers spaced on approximately 4-ft. centers. The weighted rolls serve to straighten any twist or warp. A controlled force is applied at the midpoint between rollers by an air cylinder. The deflection caused by the force is read on an indicating dial. The actual grade is obtained from a chart that relates the deflection and cross section to the grade of the piece. While this device could be automated, it is currently available only in this form.

Operating Speed:

4 pieces/min

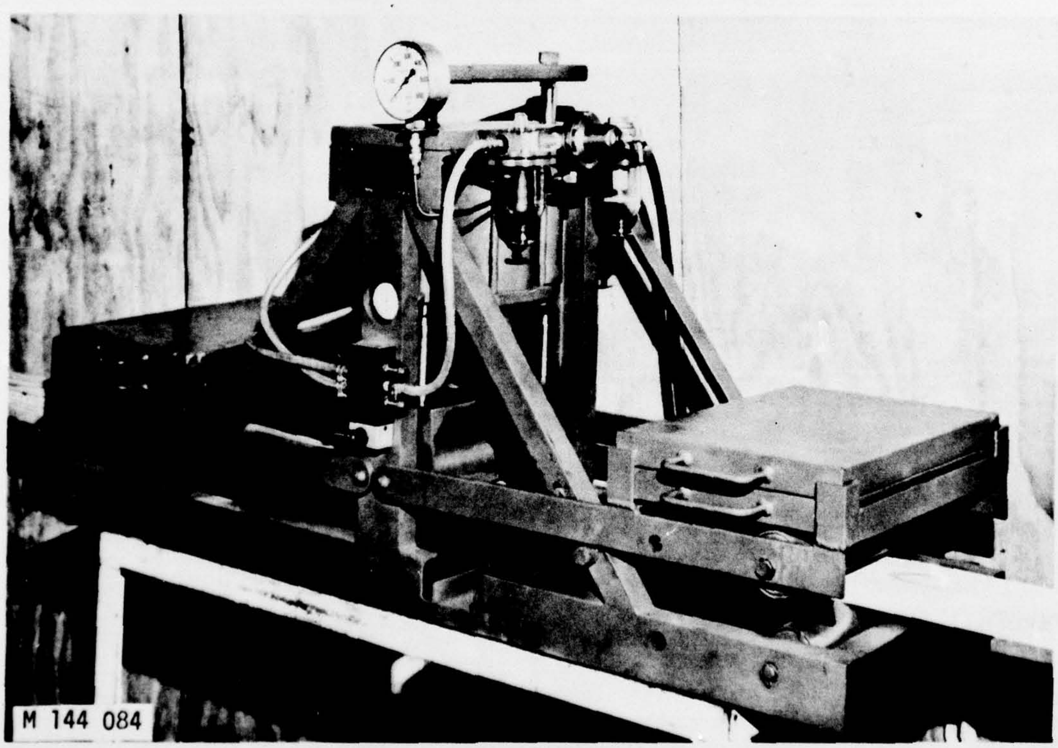

Figure 39.--TRU.

(M 144 084)

Material Size:

Thickness - 1 to 2 in.
Width - 2 to 12 in.
Length - 4 ft to practical limit

Installation Requirements:

Machine is portable and need only be set on a level firm base.

Air supply - 100 psi

E-Computer (fig. 40)

Manufactured By: Machine Cost: $25,000

Irvington-Moore
P.O. Box 23038
Portland, Oreg. 97223

Operating Principle:

The E-Computer computes the dynamic modulus of elasticity of a board or timber by measuring its weight and period of vibration and combining these in a formula with the length, and cross-sectional dimensions provided in a scaling factor.

The piece is placed on knife-edge supports, one of which contains a load cell for measuring weight. Vibration of the piece is induced by tapping it with the hand. Momentarily depressing a "compute" pushbutton on the face of the machine causes "E" to be computed and displayed on a direct digital indicator. The machine will also read out the piece weight on command.

Operating Speed:

Maximum - 4 pc/min

Material Size:

Any cross section and length that can be induced to vibrate at its natural frequency up to approximately 10,000 lbs maximum weight.

Installation Requirements:

Portable, knife-edge supports must be on a level firm footing.

Electrical service - 120V, 3 phase, 60 cycle.

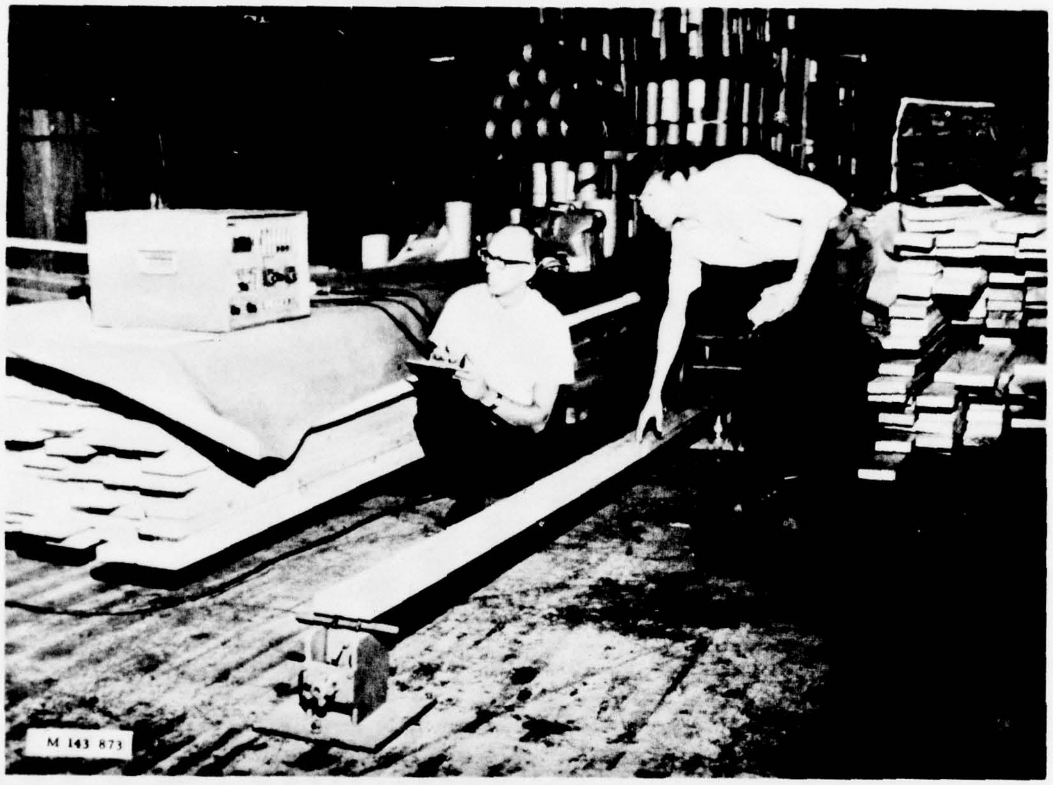

Figure 40.--E-Computer.

(M 143 873)

Stress-Wave MOE Computer (fig. 41)

Manufactured By: Machine Cost: (less peripheral equipment)

Porter Engineering Limited
109 W. 6th Ave.
Vancouver, British Columbia

$25,000

Operating Principle:

The Stress-Wave MOE Computer computes the modulus of elasticity of a board or timber by measuring the velocity of sound and the density of the piece. The piece is placed on three load cells connected in series to measure the weight. The piece is struck on the end and the period of sound travel is measured. These measurements are combined with present thickness, width, length, and species values. Momentarily depressing a "compute" push-button on the face of the machine causes the average "E" to be displayed on a direct digital indicator. A series of grade stamps or colored dyes may be used to identify lumber grade classification. There are provisions for five grade classes.

Operating Speed:

10 pc/min

Material size:

Thickness - 1 to 4 in.
Width - 4 to 12 in.
Length - 8 to 24 ft

Installation Requirements:

Machine must be set into a set of transfers with a scissor hoist or other provision to load the boards onto the load cells. An outfeed table where the material can be visually check graded may be required.

Electrical service - 120V, 3 phase, 60 cycle.

Air supply - 100 psi

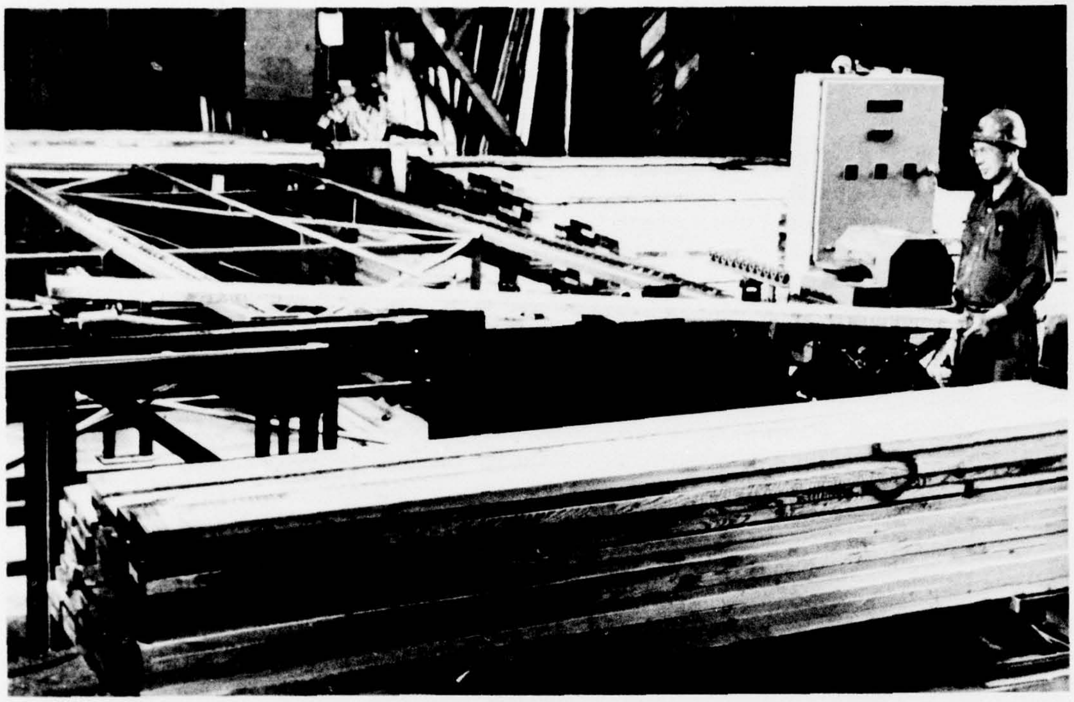

Figure 41.--Stress-Wave.

(M 143 872)

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   1970. Estimating Profits from MSR Grading, Proceedings Third Short Course, Machine Stress-Rated Lumber, Washington State University, Pullman, Wash.

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   (See latest edition). National design specification. Washington, D.C.

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   1970. American Softwood Lumber Standard, PS 20-70 Washington, D.C. 20402.

5. Western Wood Products Association, Special Product Rules.
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Appendix A--General Procedure for Mill Sample Selection for Strength Testing

1. Select approximately 200 pieces of each grade.

2. Calibrate the E measuring device. If a static tester (fig. 12) is used, the weights should be accurate within 0.1 lb.

3. Grade the stock for MSR-VQL and visual grade.

4. Label (code) each piece, then determine the moisture content and E or deflection and record this data and the two visual grades (see fig. 11). Deflection shall be recorded to the nearest 0.001 inch. The data collected should include for each piece the following information:

    a. Piece number (code).

    b. Visual quality level.

    c. Visual grade.

    d. Moisture content at time of plant deflection test.

    e. E measurement or deflection on plant static tester. The location where the E or deflection was taken shall be marked on the "up" side of the piece.

5. Specimens to be sent to a testing laboratory for strength tests are selected to provide a sample stratified on E and VQL; this means approximately equal numbers of specimens at all possible levels of E and VQL should be selected, if possible. To do this, specimens previously divided into VQL classes are further divided into narrow E classes. Equivalent deflection classes can be used if E values have not yet been computed. Specific specimen numbers for test then can be randomly selected from each category--the same number from each.

The attached data sheet for VQL-1 is an example of one way to divide and record specimens for testing. Similar sheets are used for other VQL's. Note that it is difficult to fill E categories at both extremes of E and this is also influenced by VQL. Practical rules for sampling must be adopted; grading agencies will have specific instructions.

SAMPLE FOR STRENGTH TEST--VQL-1

Plant E (10^6 psi) Range	Equivalent Deflection (Inches) Range	Piece Number				
		1	2	3	4	5
< 0.55						
0.55-0.70						
0.70-0.85						
0.85-1.00						
1.00-1.15						
1.15-1.30						
1.30-1.45						
1.45-1.60						
1.60-1.75						
1.75-1.90						
1.90-2.05						
2.05-2.20						
2.20-2.35						
2.35-2.50						
2.50-2.65						
2.65-2.80						
> 2.80						

Appendix B--Mill Locations of Stress Grading Machines

I. Continuous Lumber Tester

Simpson Timber Co.
Shelton, Washington

Weyerhaeuser Co.
Snoqualmie Falls, Washington

Frank Lumber Co.
Mill City, Oregon

Brand "S" Corp.
Portland, Oregon

Bohemia Lumber Co.
Cottage Grove, Oregon

Roseburg Lumber Co.
Roseburg, Oregon

Cedar Products
Mill City, Oregon

Willamina Lumber
Willamina, Oregon

Pope & Talbot Lumber Co.
Port Gamble, Washington

Pope & Talbot Lumber Co.
Midway, B.C. Canada

II. Stress-O-Matic

Brunswick Lumber Products
Nevada City, California

Weyerhaeuser Tech Center
Longview, Washington

Roseburg Lumber Co.
Dillard, Oregon

Cascade Locks Lumber Co.
Cascade Locks, Oregon

Gulf Lumber Co.
Mobile, Alabama

Merril Wagner Lumber Co.
Williams Lake, B.C. Canada

Trus-Joist
Azalea City Industrial Park
Valdosta, Georgia

Crown Zellerbach Lumber Co.
St. Helens, Oregon

III. Computermatic

None

IV. TRU Timber Grader

None

V. E-Computer

Weyerhaeuser Co.
Tacoma, Washington

Forest Products Lab.
Madison, Wisconsin

Columbia Research & Testing
Santa Rosa, California

Timber Products & Testing Service
Lithonia, Georgia

VI. Stress Wave MOE Computer

Koppers Co.
Burnaby, B.C.

U.S. Forest Products Laboratory.

Machine stress rating: Practical concerns for lumber producers, by William L. Galligan, Delos V. Snodgrass, and Gerald W. Crow. Madison, Wis., For. Prod. Lab., 1977. 83 p.(U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. FPL 7.)

Documents guidelines for understanding machine stress rating. First part deals with principles of stress grading by machine; second with methods of lumber yield assessment; and the third with mill mechanical analysis and cost analysis.

U.S. Forest Products Laboratory.

Machine stress rating: Practical concerns for lumber producers, by William L. Galligan, Delos V. Snodgrass, and Gerald W. Crow. Madison, Wis., For. Prod. Lab., 1977. 83p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. FPL 7.)

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